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THE VARIATION OF MOISTURE WITH
LITHOTYPE AND OF NITROGEN AND CERTAIN INORGANICS
WITH PETROGRAPHY IN YALLOURN SEAM BROWN COAL

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Lithotype Banding in Dried Coal Face

NO 1 A Level, Yallourn Open Cut

The information presented herein is the result of specific investigations carried out by the author and is not extracted from or based upon the work of others except where indicated by reference. Unless stated otherwise, all text, illustrations and appendices are, apart from the geological figures in Section 3, the work of the author.

Data given are the property of the State Electricity Commission of Victoria but may be referred to or used with proper acknowledgement.

The work presented in this thesis has not been submitted for a degree or similar award to any other university or institution.

R J Gaulton

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ABSTRACT

A tendency for darker lithotypes in Latrobe Valley brown coals to possess a higher bed moisture content than adjacent lighter lithotype coal has for some time been noted. Although the range of moisture values relating to this is generally limited to only a few per cent by weight, evidence exists to suggest that such apparently minor differences in bed moisture can and do exert a disproportionally large effect on the net output of large brown coal-fuelled thermal power stations. Samples taken over an 18 metre length of coal core obtained in Yallourn Open Cut show a correlation between moisture and lithotype, with the darker lithotypes tending to have the highest moisture and pale lithotype the lowest. A high degree of correlation is also evident between nitrogen and the amount of residual woody material present and between nitrogen and the concentration of calcium, magnesium and iron as soluble cationic species in the coal. As a result, it is shown that the small scale distribution of certain inorganic constituents is influenced by petrographic structure.

1 INTRODUCTION

The moisture content of soft brown coal is an important parameter that provides the best single indicator of physical rank and effectively determines the net and gross wet specific energies of the coal [SECV 1980].

It has long been known that variation in moisture in Latrobe Valley brown coal is related to -

- individual seams;
- depth within a seam;
- tectonic history; and
- structure.

Moisture commonly shows a regular decrease with depth within a single seam and from one seam to another [Allardice et al 1977], the only exceptions being where tectonic or local structural effects have distorted this trend.
Recent studies that have taken account of coal lithotype suggest that a relationship also exists between moisture and lithotype [George 1972, SECV 1980, Kiss 1982(b)]. This appears as a small but nevertheless significant tendency for moisture to be lower in lighter lithotype and higher in dark lithotype coals. It has been noted also that coal with a high wood content commonly yields a higher than usual moisture content.

The principal aim of the study is to investigate further the variation in moisture content within a vertical sequence of coal containing a range of lithotypes and to demonstrate the degree of correlation between bed moisture and coal lithotype or any other parameter to which moisture appears to be significantly related. Findings relevant to this topic are presented in Section 5, while the effect and significance of moisture variation is outlined in Section 6.

In addition, strong correlations between various other constituents of the coal emerge from the analytical data. Some of these relationships were not anticipated and these are treated within Section 7.

2 FORMAT OF STUDY

2.1 General

From the top of the currently exposed Yallourn Seam to its base - a vertical interval of approximately 70 metres - borehole and open cut analyses show that average moisture content decreases by between 3% and 4%. This trend, which corresponds to the slight but consistent increase in rank with depth [Gloe 1960], would effectively mask any variation of moisture with lithotype should sampling be random, widely spaced, fixed interval or otherwise unrelated to lithotype [Hibbert et al 1981]. It was considered, therefore, that the most suitable means by which moisture variation could be studied was either to obtain a series of face samples in a vertical channel type sequence within an open cut, or to obtain a continuous coal core. The latter method was chosen as the possibility of samples having been affected through their proximity to dry, exposed coal is eliminated in bore samples.

The Yallourn Seam, with its high moisture content and wide range of relatively distinct lithotypes, was selected as a suitable seam on which to base this investigation. An 18 metre interval of coal core - 100 mm diameter - was obtained from Bore 3651 N, drilled during August 1981 from No 2 level in the western batters of Yallourn Open Cut (Appendix 7) to a total depth of 22 metres from the surface.

2.2 Sampling

On removal from the core barrel, the coal was immediately wrapped and sealed in plastic to minimise moisture loss. At the laboratory, it was removed from the plastic and sliced in half longitudinally on a small bandsaw in order to provide duplicate columns, one to be laid out for air drying and one for chemical and petrographic analysis. Division of the latter segment into 0.3 metre intervals then gave the required suite of continuous vertical samples.

In a normal situation of 100% core recovery, the 18 metres of coal represented by the core recovered would have yielded sixty 0.3 metre lengths of core. However, core recovery totalled only 90% because of the presence of some fracture zones within the coal. Consequently, the number of samples was reduced to 50 with some of necessity representing intervals greater than 0.3 m (Appendix 6.1). The locations of these samples can be seen from the bar charts shown in Figure 8, with the larger interval samples corresponding to 8.5 to 9.8 and 9.8 to 10.8 metre depths.

2.3 Analyses

2.3.1 Lithotype

A lithotype log (Appendix 5) was produced following visual and physical examination of the coal core in its air dried state. Logging took place eight weeks after the coal had been laid out to dry indoors, where both natural and artificial light was available.

The lithotype log as determined from visual inspection is shown in Figure 8 where it can be compared directly with the colour index log derived from measurements on the 'Hunterlab' colour meter (Appendix 3).

Although the visual and colour index logs correlate reasonably well, a few marked discrepancies are evident. These arise partly because the visual log determined on lump coal is a subjective assessment and colour index measurements, although objective, may be sensitive to certain variables, such as the amount of light coloured leaf cuticle present and the size distribution of particles in the ground sample (Appendix 3). All lithotype logging and colour index determinations were carried out by the author.

2.3.2 Chemical Analyses

The analytical determinations performed on each of the 50 samples were as follows:

> Moisture, ash, iron (non pyritic), calcium, magnesium, sodium, chlorine, sulphur, gross dry specific energy, gross wet specific energy and net wet specific energy with nitrogen determinations carried out on 17 selected samples. The results of these determinations are tabulated in Appendix 6.1.

Mineral and Inorganic Constituents

The inorganic or ash forming constituents of Latrobe Valley brown coal are almost entirely of epigenetic origin and are divided into two categories [Kiss & King 1977].

i Minerals.

ii Inorganics.

i Minerals

Minerals in brown coal result largely from post depositional invasion of detrital matter into the coal mass via open joints and cracks or other physical routes [Kiss & King 1977]. Consequently, minerals normally occur as discrete particles consisting primarily of quartz, kaolinite and pyrite/marcasite. The minerals in brown coal are chemically expressed as follows:

$$\text{Minerals} = SiO_2 + Al_2O_3 + TiO_2 + K_2O + FeS_2{}^*$$

* The iron sulphide minerals are deposited as a result of hydrothermal activity rather than detrital invasion.

Obviously, the inclusion of minerals bears little relationship to lithotype, coal petrology or moisture content and chemical determinations of mineral matter were not carried out for this study. Mineral matter was, however, measured optically on those samples subjected to petrographic analysis (Appendix 6.2).

ii Inorganics

The inorganics are a group of cations and water soluble salts extractable or exchangeable by using dilute hydrochloric acid [Kiss 1982(b)]. In terms of chemical analysis, the inorganics are defined as -

$$\text{Inorganics} = Na + Ca + Mg + Fe + (Al) + (Si) + NaCl$$

where Fe refers to the non pyritic form and (Al)/(Si) to the acid soluble Al and Si. The abovementioned expression does not take into account that some Fe and Al can be present as hydroxide, but this is usually negligible [Kiss 1982(b)].

Inorganics are introduced into the bed moist coal by the permeation through it of groundwater containing dissolved salts, cations of which (Ca^{++}, Mg^{++}, Na^{+}, and Fe^{++}) exchange with carboxylic groups in the coal [Kiss & King 1977].

This process is known as ion diffusion and the distribution and concentration of inorganic constituents in a coal seam will depend on such influences as -

- the cationic species in the groundwater moving through the coal;
- the degree of exposure of the coal seam to aquifers;
- the proximity and composition of adjacent sediments; and
- the amount of leaching or flushing, if any, to which the coal has been subjected.

In many instances, coal seams or zones within coal seams show concentration profiles with depth of some or all of the inorganic constituents [Kiss 1982(a)], the presence of such profiles being seen as further evidence of mobility of the inorganics.

The soluble cations Na, Ca, Mg and Fe generally comprise a substantial part of the inorganic component in the coal and are commonly the major ash forming constituents. Analysis for these elements was performed not only to confirm that their occurrence is largely unrelated to lithotype but also to explore the possibility that previously undefined relationships may exist.

Nitrogen, Chlorine and Sulphur

Determinations of nitrogen were carried out on selected samples to further investigate the possibility that nitrogen content is inversely related to the amount of wood present in the coal [SECV 1980].

The observed correlations between nitrogen content and residual woody tissue and between nitrogen and the inorganics Ca, Mg and Fe, are treated under Section 7.

Chlorine was determined in order to detect any possible relationship with moisture and/or lithotype. Although a statistically significant degree of correlation does exist between moisture and chlorine ($r = -0.34$, Appendix 2) this is not considered strong enough to justify a more detailed investigation. The determination of sulphur content was included in order to identify any zone of high sulphur which might occur within the sequence sampled. From the results, it is apparent that no such zone was encountered in Bore 3651 N.

All chemical analyses were conducted by staff of the Coal Science Section, Research and Development Department, under routine conditions, standard methods and techniques being used (SECV, 1978).

2.3.3 Petrographic Analyses

Full maceral and maceral group analyses were performed on 25 selected samples using grain mounts prepared by standard methods (SECV, 1978) (see Appendix 9).

For each sample, 500 point counts were made in plain reflected light and a further 500 counts were made, for purposes of liptinite determinations, in fluorescent light under blue light excitation.

The percentage 'free wood' present was estimated using the technique described under Appendix 4. All petrographic determinations were performed by the author, and the results of these are tabulated under Appendices 6.2 and 6.3.

3 GEOLOGY

3.1 General

The Latrobe Valley Coal Measures lie within the Latrobe Valley Depression, an on-shore extension of the Gippsland Basin (Figure 1). Of Tertiary age, the brown coals of the Latrobe Valley comprise the major deposits of brown coal in Australia [Gloe 1975]. The Latrobe Valley Coal Measures range up to about 770 metres in thickness in the Latrobe Valley Area [Brumley et al 1981] and consist for the most part of a fluviatile sequence of kaolinitic clays, brown coals and unconsolidated silt, sands and gravels. The seams of coal are typically extremely thick and although possessing a high moisture content are normally low in ash. Individual coal seams up to 255 metres thick have been recorded, with even greater thicknesses of coal existing with only minor clay breaks in some areas [Gloe 1976]. Some flows of basalt are interbedded with the coal seams, but these are generally restricted in their occurrence to around the western and southern margins of the Latrobe Valley Depression. Various deep aquifers, mostly of sand, occur within the Tertiary sequence and are artesian in places. Dewatering activities at Morwell Open Cut have, however, resulted in local depressurisation of underlying aquifers with more widespread effects detectable through much of the coalfield areas [Brumley et al 1981]. The geology of the Latrobe Valley Coal Fields, overburden removed, is shown in Figure 2, with a complementary series of cross sections shown in Figure 3. Major economic coalfields are shown in Figure 4, while Figure 5 gives an indication of the relative size and extent of the Latrobe Valley coal deposits.

3.2 Structure

The Latrobe Valley Depression consists of an elongate, asymmetric syncline which plunges to the east and north-east (Figure 2). This structure is downfaulted between Palaeozoic sediments of the Eastern Highlands to the north and Early Cretaceous sediments, which form the South Gippsland Highlands, to the south (Figures 1, 6). The Mesozoic sequences also comprise most of the "basement" rock underlying the coal measures and consist largely of arkosic sandstones of terrestrial origin.

To the west, the Latrobe Valley Depression is separated structurally from the neighbouring Moe Swamp Basin by a basement high known as the Haunted Hill Block (Figure 6), over which the coal seams are relatively thin and discontinuous. The Tertiary sediment pile thickens to the east where the older units of the coal measures dip below sediments of an upper Tertiary marine transgression which peaked during the Miocene [Hocking 1976].

Structural aspects of the Latrobe Valley Depression were described originally by Thomas and Baragwanath (1949) and more recently by Gloe (1975) and by Hocking et al (1976). The major structural elements are arranged en echelon with a general north-east to south-west orientation (Figure 2). Among the more important structures which control the geology and disposition of the coal fields are the Yallourn, Morwell and Rosedale Monoclines, the Baragwanath Anticline, the Loy Yang Dome (east-west trend) and the Traralgon and Gormandale Synclines (Figures 3, 6). For the most part, these structures are related to fault displacements within the basement rocks and are considered to be subdued reflections of such movements [Barton 1981]. The structures have generally been truncated by erosion (Figure 6) and the major open cut developments are located where thick coal seams now lie close to the surface (Figure 3). Between the major structures, the development of very broad open folding has resulted in a series of gentle north-east and south-east pitching synclines and anticlines.

Although fault displacement of coal seams appears to have taken place adjacent to some of the more pronounced structures, faulting within the coal seams exposed by mining in the Yallourn/Morwell area is either absent or of a minor nature. Jointing within the currently exposed seams is, however, strongly developed and consists mainly of smooth walled near vertical fractures, many of which can be traced throughout the entire depth of the seam. This jointing is considered to have propogated in response to approximately north-south regional compressive stresses active during Upper Tertiary to recent times [Barton 1981].

3.3 Stratigraphy

The Latrobe Valley Coal Measures, or "Latrobe Valley Group" [Hocking 1972], range in age from Upper Cretaceous to Recent (Hocking, 1976). A rock correlation taken from Gloe (1975) is shown in Figure 7, for five geographic areas from Thorpdale, at the western end of the depression, to Coolungoolun near the eastern end.

As can be seen, the coal measures are subdivided into the Traralgon, Hazelwood, Morwell and Yallourn Formations in general order of decreasing age. A net westerly shift of the main coal forming environments during the Tertiary is apparent, resulting in the younger coal seams being located towards the western end of the Latrobe Valley Depression, with the older seams occurring further east. The generalised stratigraphic and spatial relationships for the major seams are apparent from Figures 2 & 3.

Uncomformably overlying the Latrobe Valley Coal Measures are the Haunted Hill Gravels, which form the overburden in the current open cut areas. The Haunted Hill Gravels comprise a widespread, blanketing deposit of sand, clays and gravels of greatly variable thickness, ranging from less than 9 metres thick in some areas to over 90 metres thick in the major synclines [Gloe 1975]. The most favourable overburden to coal ratios are naturally encountered where thick coal seams are overlain by only a thin veneer of the Haunted Hill Gravels, such as in the non-synclinal areas at Yallourn, Morwell and Loy Yang.

3.4 Geological History

Commencing during the early Cretaceous, a thick pile of largely terrestrial coal bearing sediments, mainly arkose, greywake and conglomerate, accumulated rapidly within the Strzelecki Basin, a downfaulted and epeirogenically downwarped precursor of the Gippsland Basin [Hocking 1972]. These sediments are known collectively as the Strzelecki Group, and are thought to achieve an onshore thickness of up to 6000 metres [Douglas 1976].

Deposition of the Latrobe Valley Group commenced during the middle to late Cretaceous in the now offshore eastern and central areas of the Gippsland Basin. The westerly migration of coal accumulation depocentres which subsequently took place is attributed to a declining rate of subsidence within the basin coupled with an increasing rate of sediment supply [Hocking 1972].

Holdgate (1984) has shown that this westerly trend was punctuated by a local reverse and return migration of coal depocentres during formation of the Morwell 2, Morwell 1A and 1B and Yallourn seams. This is attributed by Holdgate to the effects of more rapid compaction of the coal relative to surrounding syndepositional inorganic sediments, causing the thick layers of peat or coal to become sediment sinks while adjacent areas containing little or no organic sediment in turn become new coal depositional environments. This process is by nature effectively independent of eustatic changes in sea level.

The subsidence, which persisted generally until Miocene times, is thought to have been the result of taphrogenic movements and associated fault block adjustments which continued subsequent to the opening of the Tasman Sea [Smith 1982]. This was accompanied by periodic outpouring of basalts (Thorpdale volcanics) which, as mentioned previously, are interbedded with the Latrobe Group sediments proximal to the western and southern margins of the Latrobe Valley Depression.

A marine transgressive sequence represented by the Gippsland Limestone and Lakes Entrance Formation peaked during the middle Miocene at the eastern end of the Latrobe Valley Depression. Sediments of this transgression are known to overlie sediments of the Traralgon Group but are considered to be time equivalents of the upper Latrobe Valley Coal Measures [James & Evans 1971].

Following deposition of the Yallourn Group, further accumulation of the Latrobe Valley Coal Measures was terminated by a phase of uplift. This was accompanied by extensive faulting in the basement rock with formation of the major structural elements within the Latrobe Valley Depression.

Widespread erosion in the late Miocene and early Pliocene followed, during which a substantial thickness of the coal measures was removed and many of the major structures were truncated [Gloe 1975]. Finally, the Haunted Hill Gravels were deposited disconformably across the eroded surface of the Latrobe Valley Group in association with the Pliocene Kosciousko Uplift [Jenkins 1976].

3.5 Coal Properties

- Composition

In general terms, the brown coals are comprised of a finely divided groundmass of plant detritus impregnated to varying degrees by humic substances and containing a large range of partially preserved plant tissues. Such tissue inclusions range from microscopic in size to massive tree trunks, branches and stumps (Prints 1, 4, 5, 6), some up to 2 metres in diameter. Seams of brown coal in the Latrobe Valley also exhibit the macro layering known as lithotype banding, which represents variations in the type of coal and is central to the objectives of this study. Petrographic properties and basic petrographic relationships are further discussed in Section 4.5.

. Ash Yield

The ash yield of brown coals in the Latrobe Valley is characteristically low, mostly within the range of 1% to 4% by weight on a dry coal basis (Table 1). Even so, the presence of certain inorganic constituents or, in some cases, a particular combination of inorganic constituents, can be strongly detrimental to the burning properties of the coal and its tendency to slag or otherwise foul boiler surfaces [Kiss 1982]. The discharge of combustion by-products from power stations is also affected, as levels of certain particulate and gaseous emissions are influenced by the nature of mineral and inorganic constituents within the coal.

. Moisture Content

Average moisture contents for Latrobe Valley brown coals range from around 50% to nearly 70% (Table 1). Bed moisture content is in part a reflection of the degree of consolidation which has taken place [Gloe 1976] and therefore tends to decrease with depth, both within seams and from one seam to another. This trend is not uniform however, and many localised aberrations related to structure, tectonic compression , coal lithotype and other undetermined effects have been recorded. The variation of bed moisture with coal lithotype as shown by the results of this study is the subject of Section 5.

TABLE 1

LATROBE VALLEY BROWN COALS : COAL QUALITY

COALFIELD	YALLOURN (YALLOURN SEAM)	MORWELL (M1 SEAM)	YALLOURN NTH EXT (LATROBE SEAM)	LOY YANG (M1B SEAM)	GORMANDALE (TRARALGON SEAM)	GOOLUNGOOLUN (TRARALGON SEAM)
Moisture %	66.8	60.9	52.9	62.5	56.0	53.1
Ash (db) %	1.8	3.2	4.8	1.5	2.5	2.6
Volatile matter (db) %	51.7	49.8	48.8	51.3	52.2	47.4
Carbon (db) %	65.9	67.1	65.7	68.3	66.1	68.2
Hydrogen (db) %	4.6	4.8	4.6	4.8	4.8	4.8
Net Wet Specific Energy (MJ/Kg)	6.5	8.5	10.2	8.1	9.5	11.5
Gross Dry Specific Energy (MJ/Kg ash free)	25.8	27.3	26.7	27.0	26.4	29.2

. Calorific Value

A corollary of the low rank and high moisture content in Latrobe Valley brown coals, is the relatively low net wet calorific values shown in Table 1. In spite of this, the brown coals are used in their raw state to fuel large thermal power stations supplying the greater part of the State of Victoria's electricity requirements.

3.6 Reserves

Reserves of brown coal are listed both on a geological basis, which incorporates the total resource, and as mining reserves using a basis of realistic accessibility. Measured resources are currently calculated at around 65 000 million tonnes, with a further 43 000 million tonnes indicated. Mining reserves stand at around 36 000 million tonnes of coal with less than 30 metres of overburden above the uppermost seam, with about 12 000 million tonnes considered to be economically accessible at present day costs.

3.7 Groundwater

The Latrobe Valley Depression contains numerous deep confined and semi confined sand and gravel aquifers, many of which are interconnected within the Morwell, Hazelwood and Traralgon group sequences. Some of these aquifers contain water under artesian pressure, although this is becoming less common as dewatering activities at Morwell Open Cut continue to influence peizometric levels over a wide area [Brumley et al 1982].

3.8 Palaeobotany

Coniferous plant remains constitute most of the plant tissue recognisable in the coal. Softwood species which have been identified include Arucaria, Agathis, Podocarpus, Dacrydium and Phyllocladus [Duigan 1965, Blackburn 1981]. Angiosperm remains are not as abundant but include various Banksia, Casuarina and Myrtacea [Baragwanath 1962, Duigan 1965]. In addition, Cookson (1947) described abundant mummified leaves and pollen of a now extinct member of the family Oleaceae.

Palynological investigations [Kershaw & Sluiter 1982, Baragwanath & Kiss 1964] have identified Nothofagus as the dominant pollen group in Latrobe Valley brown coals, although other plant remains of Nothofagus are quite rare.

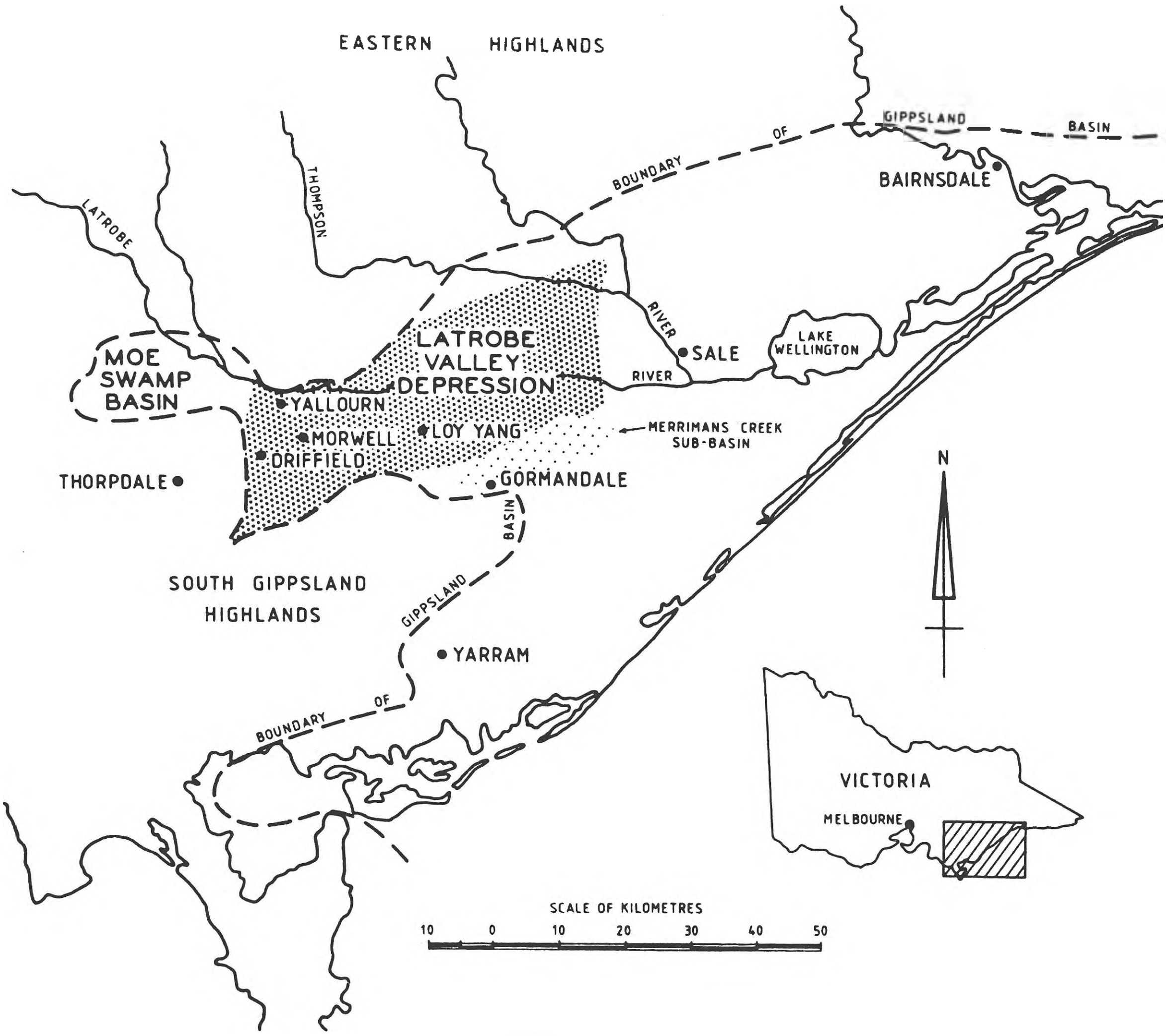


FIG 1 - LOCATION OF THE LATROBE VALLEY DEPRESSION

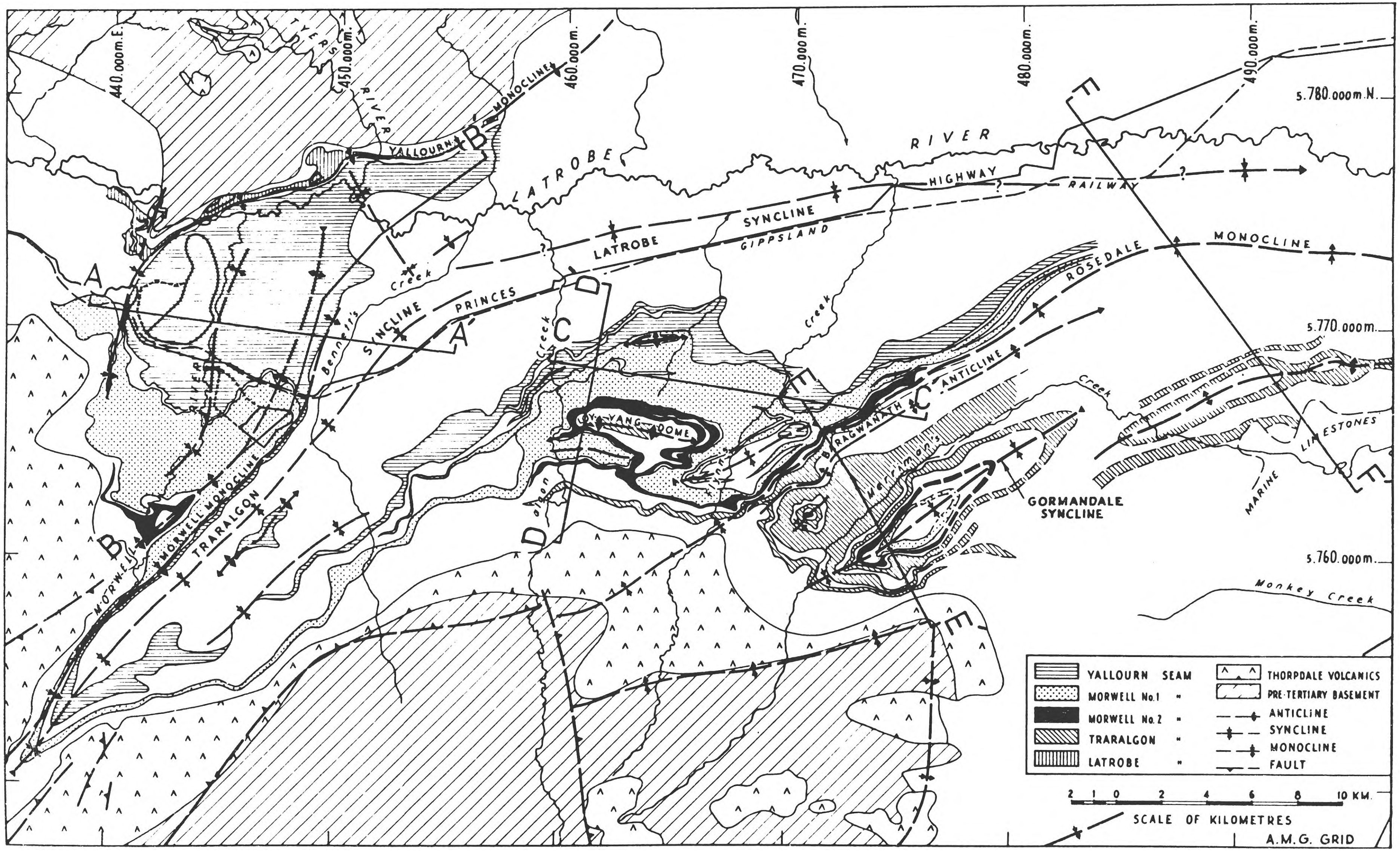


FIG. 2 — GEOLOGY OF LATROBE VALLEY — OVERBURDEN REMOVED

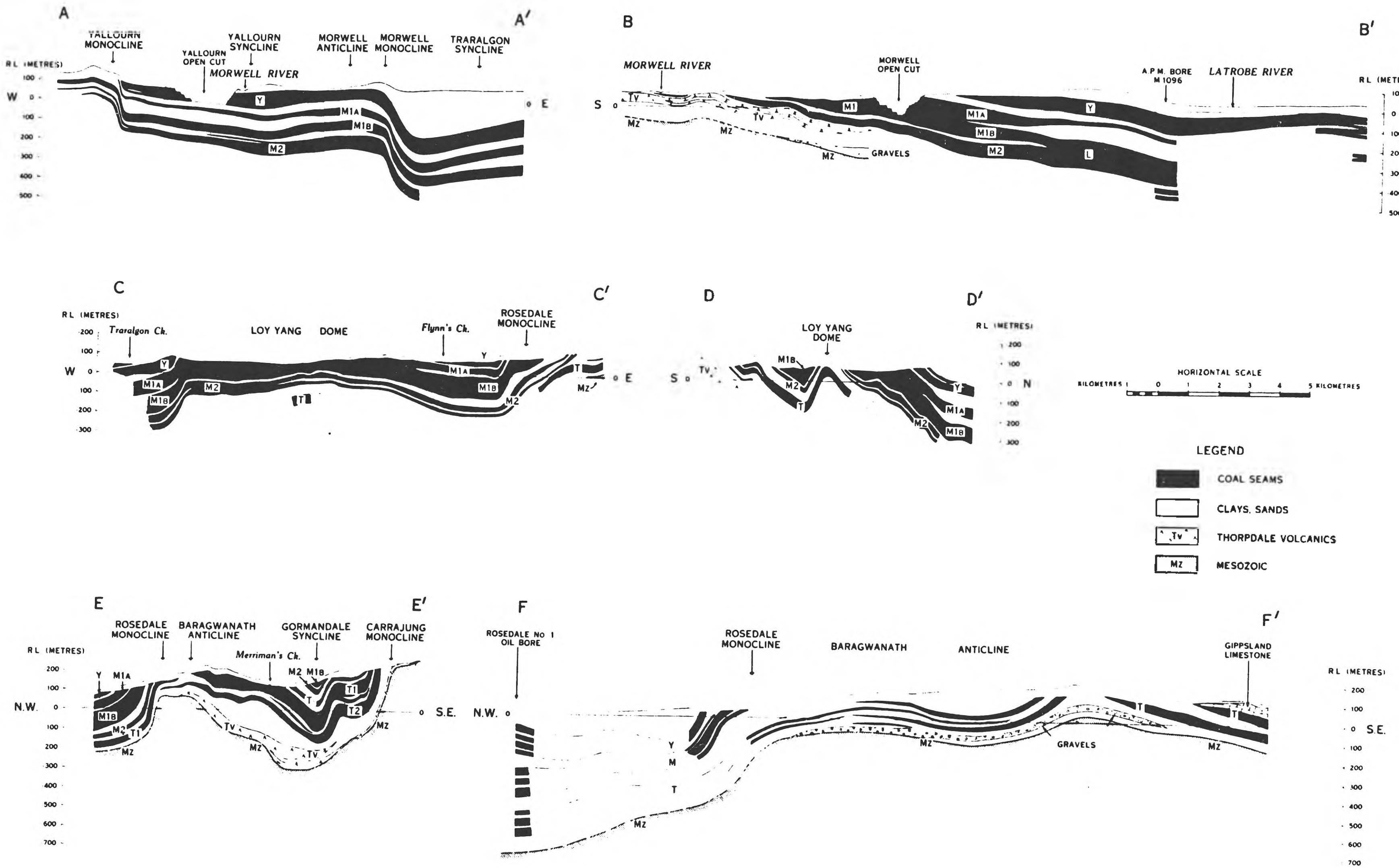


FIG 3 - CROSS SECTIONS THROUGH LATROBE VALLEY DEPRESSION

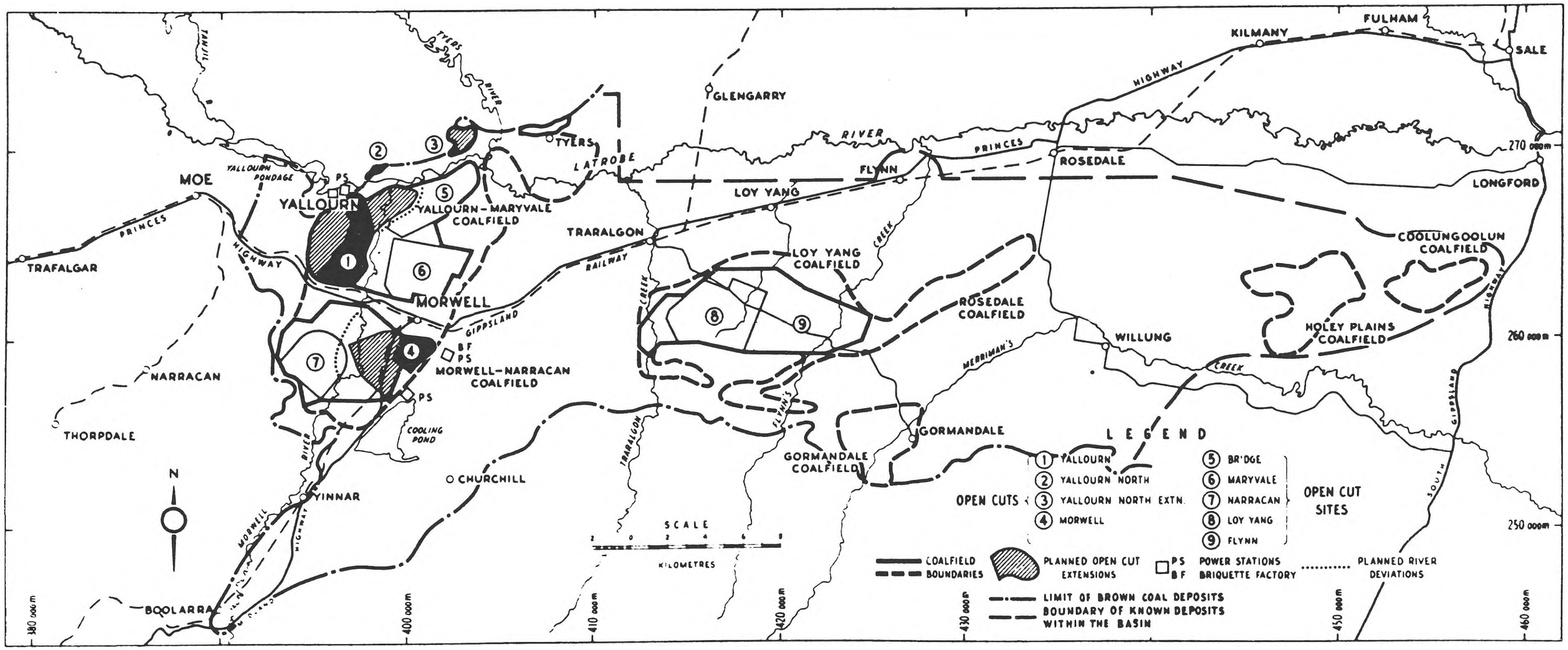


FIG 4 - LATROBE VALLEY COALFIELDS

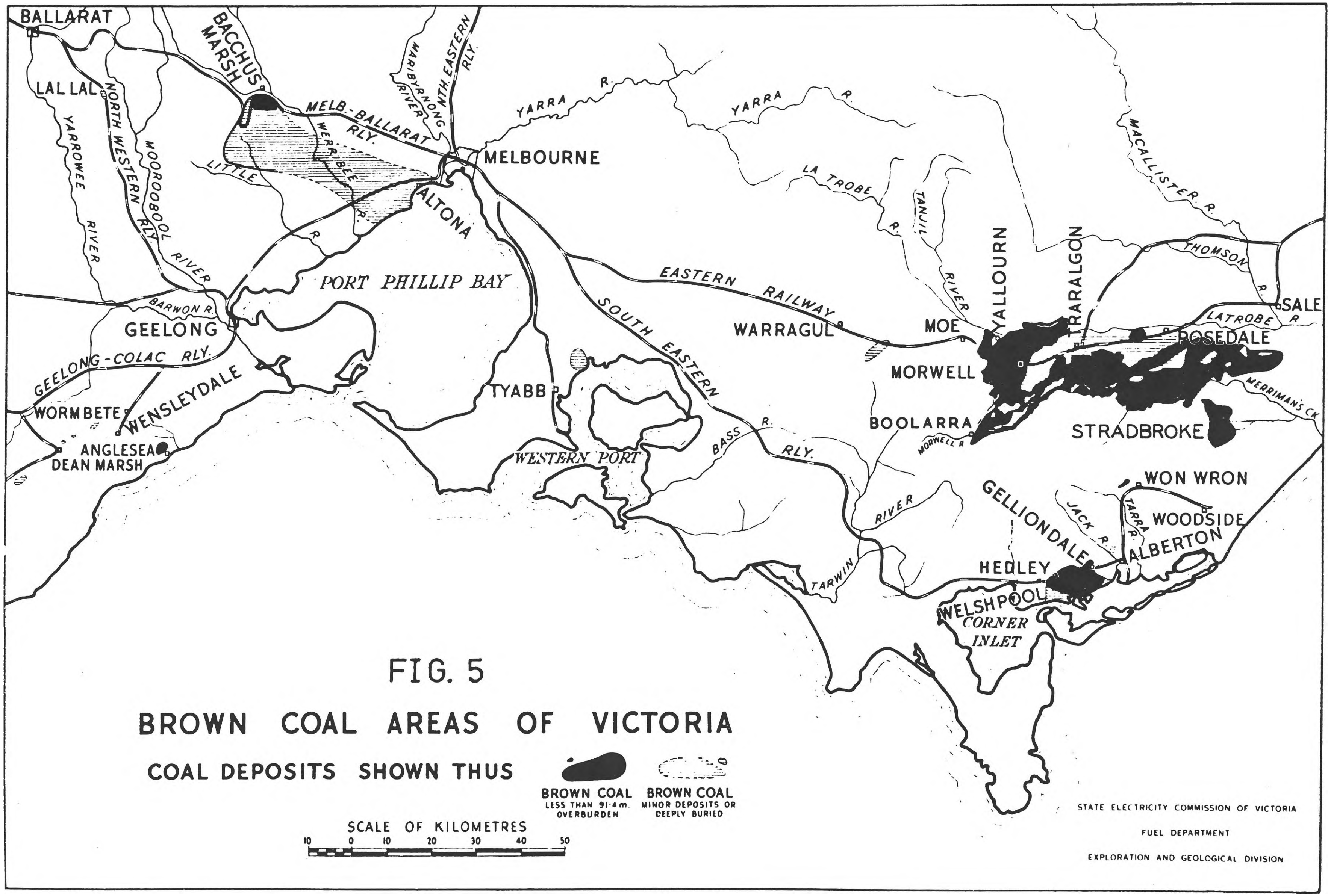


FIG. 5

BROWN COAL AREAS OF VICTORIA

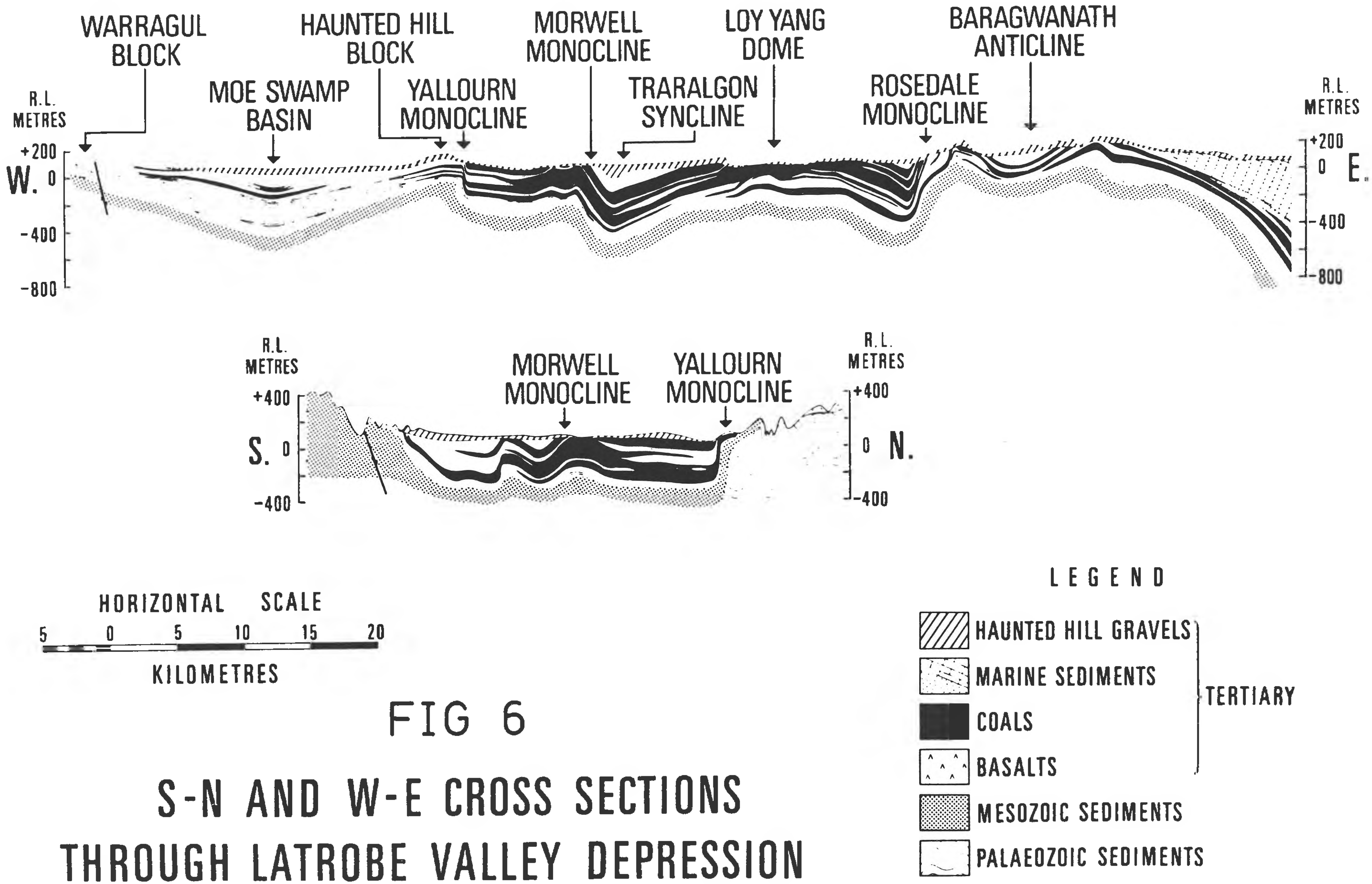


FIG 6

S-N AND W-E CROSS SECTIONS THROUGH LATROBE VALLEY DEPRESSION

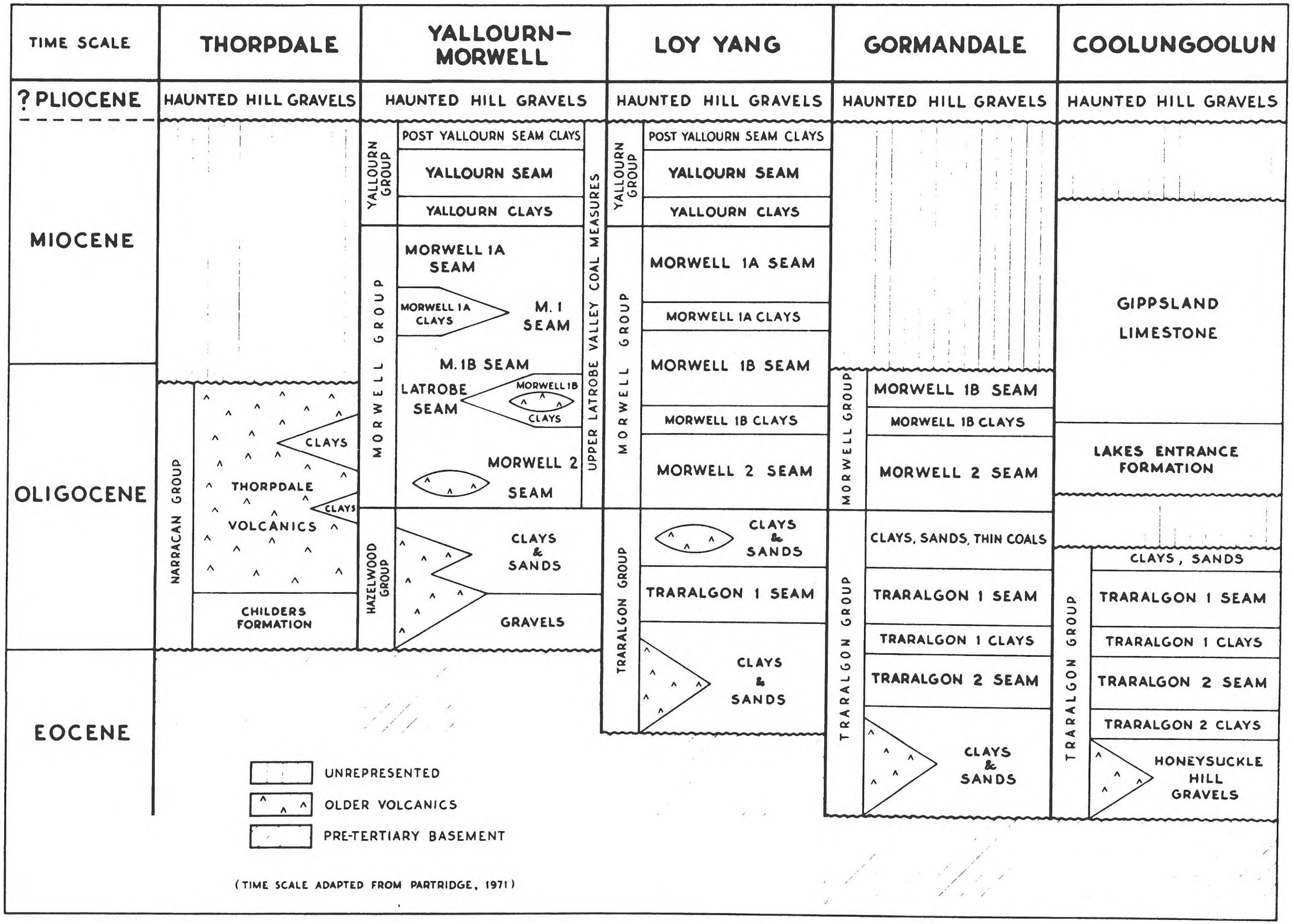


FIG 7-TIME SCALE OF MAJOR STRATIGRAPHIC UNITS-L.V. DEPRESSION

4 BROWN COAL LITHOTYPES

4.1 General

Field examination of brown coal open cut faces which have been exposed to the atmosphere for upwards of a month or so reveals that the coal mass is not homogenous, as it typically appears to be in the moist, freshly mined state, but is clearly stratified. This stratification is apparent as layers or bands distinguished mainly through variations in the colour and surface shrinkage cracking pattern of the coal, although corresponding changes in texture and palaeobotanical associations can also often be recognised (Appendix 8). Known as Lithotype Banding, this layering is a function of coal type, bearing no relation to coal rank [George 1982]. A suitably weathered coal face showing lithotype banding is shown in the photograph attached to the frontispiece of this report, while a selection of prints showing various lithotype banding visible in exposed coal faces in Yallourn Open Cut is included on following pages within this section.

The various shades of brown which characterise coal lithotype develop as the surface of the coal dries on exposure to the atmosphere. In open cut faces, this is generally confined to a depth of only a few centimetres, unless the face has been allowed to stand untouched for a very long time. The dry state colour of brown coal ranges from a very dark brown, almost black, through to a pale brown to yellowish colour depending on lithotype.

No universal system of classification for brown coal lithotypes has as yet been agreed upon by the International Committee for Coal Petrology (ICCP). There is, however, general agreement that such a classification should be based on macrosopic characteristics which can be determined in open cut faces or on hand samples [George 1982].

In conformity with this principle, George (1975, 1982) has proposed a lithotype classification for Latrobe Valley brown coals based primarily on colour and texture with weathering pattern, apparent degree of gelification* and physical properties used as supplementary characteristics. The classification proposes five basic lithotypes and in its nomenclature refers to the relative shade of brown developed by each in the dry state. This classification is presented in Table 2, along with the various supplementary characteristics used, and it is this system which has been adopted for use by the State Electricity Commission of Victoria and will be utilised in this study.

In reality, the range of lithotypes is not stepped as with the classification adopted, but is more or less continuous with a theoretically infinite number of gradational lithotypes possible. For practical purposes however, the classification given in Table 2 is considered adequate to typify, with reasonable accuracy, any sample or layer of coal in terms of its inherent lithotype.

* GELIFICATION - a process related to the breakdown and thickening of cell walls along with the formation of a largely amorphous gel-like substance permeating the coal structure. A high degree of gelification is evidenced as a black, semi-lustrous appearance of the coal in its air dried state.

It must be understood that straight visual identification of coal lithotypes is based largely on relative comparisons and therefore tends to be in part subjective (Appendix 8). This means for instance that an apparently dark lithotype recorded in the Morwell Seam may only rate as a medium dark lithotype if directly compared with lithotypes present in the Yallourn Seam. The use of colour index as a quantifiable indicator of lithotype (see Section 2.3.1 and Appendix 3) has assisted in resolving the problem to some degree, but this method is an adjunct to lithotype determination.

4.2 Origin

The Latrobe Valley brown coals are essentially autochthonous [Gloe 1975, George 1982] and lithotype banding is considered to represent changes in the depositional environment and in the plant communities from which the coal was formed. This view is advanced by George (1975) following work by Teichmüller M. AND R. (in Stach, 1982) which relates changing plant communities recognisable in brown coals of the Cologne Region in Germany to coal type.

It is generally accepted that terrestrial coal forming environments can cover a wide range, from open swamps through to damp forest [Teichmuller, M&R 1982]. The range of possible environments is primarily related to the level of groundwater, which may vary as a result of such factors as climatic cycles, seasonal fluctuations, swamp migration, subsidence and uplift, tilting, changes in drainage and biochemical variations influencing the rate of plant debris accumulation. As the environment alters, so then does the plant community, and lithotypes in the Latrobe Valley brown coals display characteristic petrographic affiliations (see Section 4.5) which appear related to specific types of plant assemblages. Other variables such as pH of the groundwater, oxygen content, temperature and redox potential of the peat and the nature of bacterial and fungal activity affect the type and degree of preservation during the early stages of peat formation [Techmüller M&R, 1982] and therefore probably also exert some influence on lithotype.

Relatively little definitive work on the origin of lithotypes in Latrobe Valley coals has been carried out. Recent palynological studies by Luly et al (1980) and by Kershaw and Sluiter (1982), as well as palaeobotanical investigations by Blackburn (1981) have suggested that the lighter lithotypes are the product of wet environments such as swamp margin and open swamp, while the darker lithotypes represent essentially drier forested environments. These findings remain contentious, however, as various indications to the contrary, mainly in the form of megascale field observations, do exist. It is, for instance, apparent that the more thick medium light lithotypes within Yallourn Open Cut contain abundant, massive woody inclusions, many in the form of large tree stumps, while such inclusions are almost entirely absent in the darker lithotypes (Prints 1, 2, 4, 5, 6). In addition, the significant observation by Blackburn (1982) that "where accumulation exceeded subsidence, the normal succession of lithotypes from pale to very dark may be seen" (p 63) is otherwise unsubstantiated by broader ranging lithotype investigations. It is also contradictory to the findings of Mackay et al (1984) that the most frequently observed cyclic progression of lithotypes is an upwards progression from <u>dark</u> through to <u>light</u> or <u>pale</u>.

PRINT 1

Dark and medium dark lithotypes overlying a thick medium light lithotype (note abundant massive woody inclusions).

No 1A Level, Southern Batters, Yallourn Open Cut

PRINT 2

Predominantly dark lithotype sequence overlying medium light lithotype.

Pivot End, No 2 Cut, Operating Faces, Yallourn Open Cut

TABLE 2.

LITHOTYPE CLASSIFICATION
TYPICAL CHARACTERISTICS OF AIR DRIED COAL

LITHOTYPE	AB.	COLOUR	TEXTURE	GELIFICATION	WEATHERING PATTERN	PHYSICAL PROPERTIES
DARK	Dk	Dark brown to black brown.	High wood content. Often small fragments.	Gelification, partic. of woody material, common.	Cracks wide and deep. Regular pattern.	Strong, hard, heavy (high S.G.)
MEDIUM-DARK	M-d	Dark brown to medium brown.	High to medium wood content. Often large pieces.	Some gelification but not extensive.	Cracks wide. Some regularity of pattern.	Strength variable, hardness and S.G. above average.
MEDIUM-LIGHT	M-l	Medium brown to light brown.	High to low wood content. Often well preserved.	Gelification uncommon. Confined mainly to wood.	Cracks shallow. Irregular pattern.	Intermediate physical properties.
LIGHT	Lt	Light brown	Medium to low wood content.	Gelification rare.	Cracks generally fine. Random orientation.	Generally soft and relatively light (low S.G.)
PALE	Pa	Pale brown to yellow brown.	Wood present but uncommon.	Gelification very rare.	Few extensive cracks.	Soft, crumbles readily, very low S.G.

<ins>Note</ins>: Texture: Wood content includes all tissue clearly distinguishable from the groundmass.
Physical Properties: S.G. = Specific Gravity.

Obviously, more work is required to properly account for the exact origin of the various lithotypes, and it may be useful to consider the observation by George (1982) that "studies confined to the macro or micro structures may be misleading, as they take no account of the large plant remains evident in the megatexture of some lithotypes".

4.3 Physical Characteristics

In addition to colour, brown coal lithotypes are characterised by various other physical properties (Table 2), some of which are readily apparent while others are the subject of exacting laboratory determinations. The main physical characteristics include texture, volume shrinkage on desiccation, specific gravity, needle hardness, porosity and moisture content.

. Colour

In addition to simple visual assessment, colour can be quantified using a colourmeter to measure the relative shade of brown on a finely ground sample of dry coal. From this, a "colour index" value is determined (Appendix 3), the higher the colour index value the lighter is the colour of the dried coal.

In using colour index as an indicator of lithotype in this study, the following scale was applied:

COLOUR INDEX VALUE	APPARENT LITHOTYPE
38 to 66	Dark
67 to 93	Medium dark
94 to 121	Medium light
122 to 148	Light
149 to 176	Pale

. Texture

The texture of brown coal results from the size and spatial relationships of the various components. Variation in texture is usually apparent as a result of differences in the amount, size and shape of the woody inclusions together with the relative degree of preservation . As suggested by George (1975), texture can be identified at three different levels of scale as follows:

a Megatexture - apparent in general visual surveillance of open cut faces.

b Macrotexture - revealed by inspection of hand specimens.

c Microtexture - textural variations visible only under the microscope.

Textural associations with lithotype do exist at each of these scales, but can be defined only as general trends. Broadly, the amount of woody material present decreases from dark through to pale lithotype. Macroscopic woody material is relatively uncommon in the dark lithotype, most of the wood existing as microscopically identifiable cellular material. Medium light lithotype coal on the other hand tends to show a lower level of microscopic wood fragments (humotelinite), but often displays numerous massive woody inclusion such as large in-situ stumps and branches.

. Shrinkage

Varying degrees of shrinkage take place as brown coal air dries to its usual atmospheric equilibrium moisture content of 10% to 15%. The amount of shrinkage displayed is strongly related to lithotype, with a high degree of shrinkage in dark lithotype coal and relatively little shrinkage in pale lithotype coal. For brown coal, the reduction in volume on air drying ranges from around 60% to about 20% [George, 1982].

Shrinkage due to air drying is largely responsible for the "weathering pattern" of shrinkage cracks which appear in mosaic like pattern on the coal surface soon after exposure to the atmosphere and continue to develop as drying proceeds (Prints 2, 4, 5). In general, shrinkage cracking shows a progression from being well developed in dark lithotypes to almost non-existent in pale lithotypes. This provides a valuable adjunct to colour and primary texture in the mapping and visual identification of lithotypes as described in Appendix 8.

. Specific Gravity

The specific gravity of bed moist coal bears a general relationship to moisture content, tending to increase as moisture decreases. This is in part a function both of the physical structure of the coal and the amount of compression to which it has been subjected. The specific gravity of bed moist coal tends not to vary greatly within a single seam, ranging for instance from around 1.10 to 1.12 for the Yallourn Seam [George 1975]. Little relationship appears to exist between lithotype and the bed moist specific gravity of coal [George 1975].

Air dried coal consists essentially of coal containing air and some water, and specific gravity determination on air dried samples apply to this assemblage and not to the actual coal material. As a result of shrinkage on drying however, the darker the lithotype the higher is the specific gravity of the coal in an air dry state.

. Needle Hardness

Needle hardness is determined by the force or weight applied to a standardised needle in order to achieve a particular depth of penetration in a prepared sample of coal. Needle hardness bears no particular relation to lithotype in fresh, bed moist coal [George 1972] but does tend to exhibit high values for air dried dark lithotype and lower values for air dried light lithotype coals of the same rank [George 1982].

. Porosity

Porosity is a direct function of the structure of brown coal. It is calculated from the helium (true) and mercury (apparent) densities of dry granular coal and is relatively low for dark lithotype coal and high for light lithotype coal.

. Moisture Content

As noted in the introduction, the bed moisture content of brown coal provides a general index of the degree of compaction to which the coal has been subjected and is also related to tectonic history and the proximity of structures. Bed moisture content also appears to be related to lithotype with a general tendency to decrease from dark through to pale lithotype [Allardice et al 1977]. A study of variation in moisture content within a limited sequence of lithotypes forms one of the major parts of this thesis and is treated in Section 5.

The moisture content of brown coal begins to fall immediately the coal is exposed to air, and for this reason determinations of moisture content are only valid if made on samples which have been subjected to an absolute minimum of exposure to the atmosphere.

4.4 Spatial Characteristics

Brown coal lithotypes usually exhibit great lateral persistence, with much of the banding visible in major open cuts traceable as individual lithotypes for upwards of two kilometres. Sequential lithotype correlations have also been established between boreholes as far apart as five kilometres. Mapping or close examination of suitable exposed coal faces does however reveal that some lithotypes lens out or phase gradually into another lithotype (Appendix 8).

The latter observation has so far been made only in regard to lithotypes which adjoin in the scale of classification, i.e. a medium light lithotype may grade laterally into a medium dark or a light lithotype, but not into a dark or pale lithotype. Lensing out is a feature most commonly observed in dark lithotypes within a medium dark sequence or vice versa.

Horizontal lithotype boundaries (i.e. bedding planes) between lithotypes may at first seem to be relatively sharp (Print 9) but closer inspections usually reveals that a graduation from one lithotype to another exists over a 0.1 m to 0.2 m interval, particularly where the adjoining lithotypes provide a good contrast. In some places such boundaries show minor contortions with small scale alternate layering and/or interfingering. This is most commonly observed where a distinctive pale lithotype comes into contact with a dark lithotype (Print 10) and constitutes a form of plant bioturbation.

Spatial features typical of the various lithotypes are summarised as follows:

a Dark Lithotypes

Dark lithotypes generally range between one and three metres in thickness, with a tendency to occur as part of a predominantly dark and medium dark sequence of lithotypes. Examples - see Prints 2, 4, 5.

b Medium Dark Lithotypes

Medium dark lithotypes appear to be thicker on average than dark lithotypes, commonly ranging between one and six metres thick. Thick bands are usually associated with a broader sequence of dark and medium dark lithotypes, while the thinner bands typically occur as relatively isolated horizons within thick medium light lithotype sequences. Examples - see Prints 3, 4, 5.

c Medium Light Lithotypes

The most abundant lithotype is probably medium light. Layers of medium light lithotype coal commonly range up to 15 metres thick, with one such horizon exceeding 20 metres in thickness at Yallourn Open Cut (refer Appendix 8).
Examples - see Prints 1, 4, 5, 6, 9.

d Light Lithotypes

Bands of light lithotype coal usually range between 0.5 and 2.0 metres thick and typically occur within a sequence of predominantly medium light lithotype. Light lithotypes located within darker sequences are usually less than one metre thick. Examples - see Prints 8, 9, 10.

e Pale Lithotypes

Pale lithotype coals are usually less than 0.3 metres thick and comprise at most only a few percent of the total coal mass in a given seam. It is often observed in the Yallourn and Morwell Open Cuts that a pale lithotype directly underlies a dark or medium dark lithotype or that a dark or medium dark lithotype will occur between or in proximity to closely spaced pale lithotype bands. Examples - see Prints 8, 9, 10.

PRINT 3

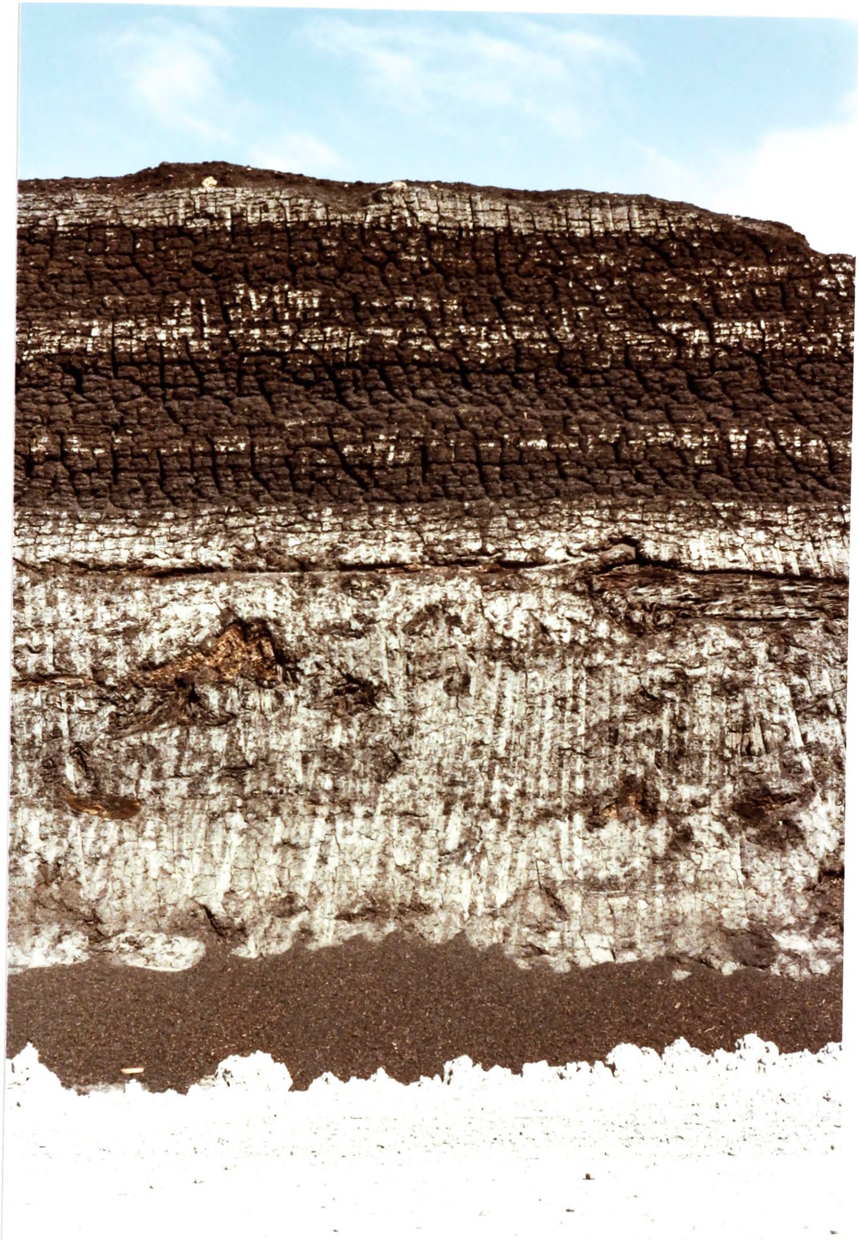
Interbedded lithotype banding - mainly medium light and medium dark - in dried coal face.

No 1 Level, 'Bulge' Area, Yallourn Open Cut

PRINT 4

Dark and medium dark lithotypes overlying thick medium light lithotype.

No 2 Level, 'Bulge' Area, Yallourn Open Cut.



PRINT 5

Detail of dark and medium dark lithotypes overlying medium light lithotype.

No 1 Level, Bulge Area, Yallourn Open Cut

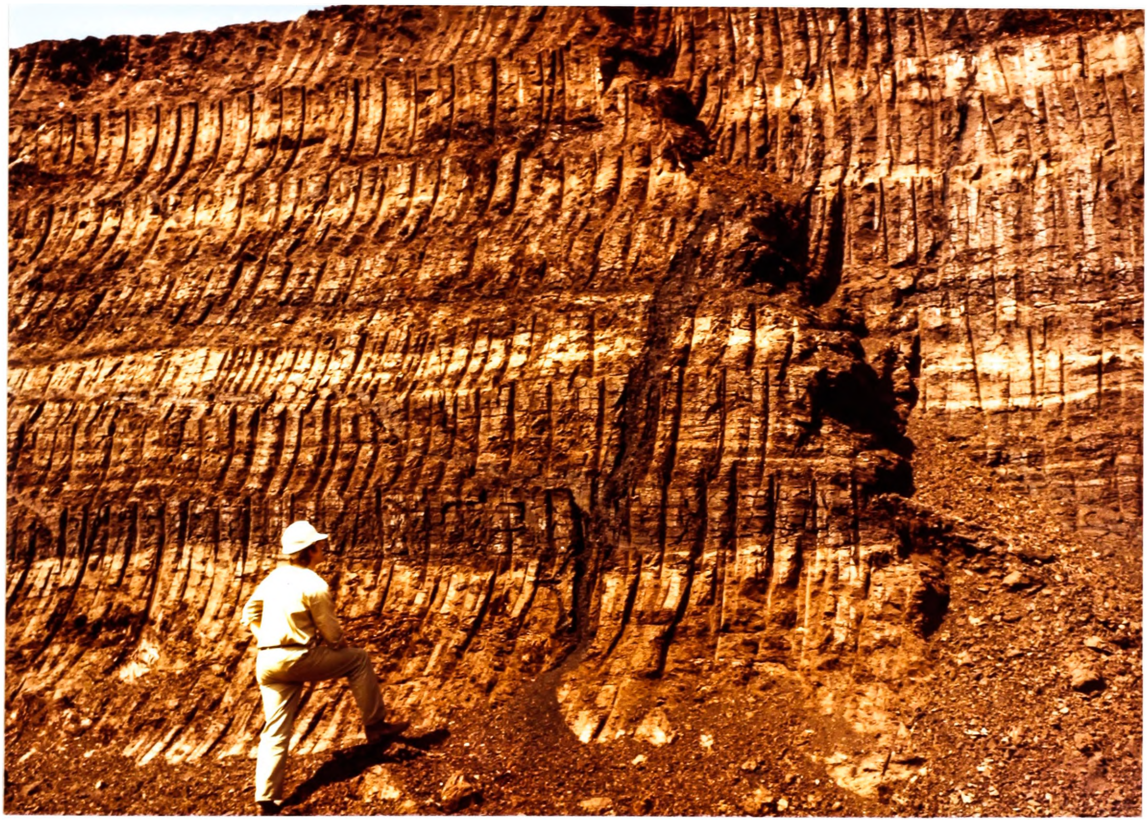
PRINT 6

Thick medium light lithotype featuring abundant massive woody remains (note coal filled vertical joint intersecting recumbent tree trunk and bordering resin inclusion (mid way up face)).

No 1 A Level, Southern Batters, Yallourn Open Cut

PRINT 7

Layered lithotypes featuring light and pale lithotype coal.
No 3 Level, South Western Batters, Yallourn Open Cut



PRINT 8

Layered lithotype banding showing pale and light lithotypes alternating with medium light and medium dark lithotypes.

No 3 Level, South-Western Batters, Yallourn Open Cut.

PRINT 9

Finely layered assorted lithotype banding overlying more massive medium light lithotype.

No 3 Level, South-Western Batters, Yallourn Open Cut

PRINT 10

Detail of interlayering of dark with pale and light lithotype coal.

No 4 Cut, Operating Faces, Yallourn Open Cut

4.5 Petrography

It has been found by George (1975) that maceral analysis can be used to accurately characterise the various lithotypes, each of which conforms to a particular range of petrographic composition. These methods can be employed to check and verify the identity of lithotypes as determined by macroscopic means. For Latrobe Valley coals, the maceral classification set down by the ICCP has been used as a basis for the SECV classification [George 1982] (Table 3).

A comprehensive definition of the various individual components of this classification is beyond the scope of this study and the reader is referred for more detailed descriptions to the ICCP Handbook (1975) and to George (1975, 1982). It will be necessary, however, to describe in general terms the major macerals and maceral groupings before attempting to summarise what is currently known of the relationships between lithotype and petrographic composition.

TABLE 3

CLASSIFICATION OF BROWN COAL MACERALS (FROM GEORGE 1975)

MACERAL GROUP	MACERAL SUBGROUP	MACERAL	SUBMACERAL
HUMINITE	Humodetrinite	Attrinite	
		Densinite	
	Humotelinite	Textinite	
		Ulminite	Texto-Ulminite
			Eu-Ulminite
	Humocollinite	Gelinite	Detrogelinite
			Telogelinite
			Eugelinite
			Porigelinite
		Corpohuminite	Phlobaphinite
			Pseudo-Phlobaphinite
LIPTINITE		Sporinite	
		Cutinite	
		Resinite	
		Suberinite	
		Bituminite	
		Alginite	
		Chlorophyllinite	
		Liptodetrinite	
INERTINITE		Fusinite	
		Semifusinite	
		Macrinite	
		Sclerotinite	
		Inertodetrinite	

To assist with developing some appreciation of the appearance and genesis of these petrographic constituents as part of the physical organic fabric of the coal, a series of 34 photomicrographs showing a variety of macerals and maceral groupings has been included under Appendix 10. These photographs illustrate the following brief descriptions of the major maceral groups.

a Humodetrinite Sub-Group

Humodetrinite comprises the coal groundmass of small ($< 10 \mu$) fragments of plant material in an amorphous matrix. The maceral attrinite is characterised by a relatively ungelified groundmass while densinite exhibits a more gelified groundmass with the constituent particles appearing more densely packed and cemented. It is usual for brown coal in the Latrobe Valley to contain 50% or more of humodetrinite. (Photomicrographs 1 to 11, Appendix 10.)

b Humotelinite Sub-Group

Humotelinite consists of recognisable plant structures, mainly the cellular remains of woody tissue, and includes roots, leaves, bark, etc. It is present in widely varying amounts, tending, of course, to be high in woody coal. The maceral textinite is essentially ungelified wood tissue, while texto-ulminite and eu-ulminite represent further stages in the gelification of such tissue. (Photomicrographs 12, 14 to 28, Appendix 10.)

c Humocollinite Sub-Group

Consisting mainly of amorphous humic gels, humocollinite also includes extensively gelified plant tissues and structureless cell excretions formed by the original plants. The various sub-macerals of this group are distinguished mainly through apparent genesis, tissue associations and microscopic appearance. (Photomicrographs 5, 10, 12, 13, 16, 18, 24, 25, 27, 28, Appendix 10.)

d Liptinite Group

Substances which fluoresce under blue light comprise the Liptinite group of macerals. Typical liptinite macerals are derived from spores, pollen, cuticle and resin and tend to be resistant to degradation, retaining much of their original structure within the coal. In general terms, liptinite is equivalent to the exinite of black coal petrographic nomenclature. (Photomicrographs 30 to 34, Appendix 10.)

e Inertinite

Inertinite comprises those macerals which tend to be chemically inert and are the last to alter during carbonisation. As with black coal, the inertinite macerals are generally hard and display a high reflectance. The content of inertinite in Latrobe Valley coals is usually less than 2% [George 1982]. (Photomicrographs 1 to 4, 8, 29, Appendix 10.)

It is well documented [George 1975, 1982] that many macerals and maceral groups show marked and generally consistent increases or decreases from dark through to pale lithotype coals.

Table 4 summarises the principal known trends among the major macerals and maceral groupings.

GROUPINGS	GENERAL TREND, DARK THROUGH TO PALE LITHOTYPE		APPROXIMATE RANGE FOR YALLOURN SEAM COAL
	INCREASE	DECREASE	(% VOLUME)
<u>Maceral Groups</u>			
Humodetrinite	*		50-70
Humotelinite		*	30-7
Humocollinite		*	10-2
Liptinite	*		2-25
Inertinite	?	?	1-3
<u>Minerals</u>	?	?	0-1
<u>Macerals</u>			
Attrinite	*		30-65
Densinite		*	20-0
Textinite	?	?	1-3
Texto-ulminite		*	15-5
Eu-ulminite		*	15- 1

(Based on data given by George - 1982, 1975)

TABLE 4 : PRINCIPAL PETROGRAPHIC TRENDS RELATED TO LITHOTYPE

4.6 Chemical Composition

It has been shown that certain chemical properties determined by proximate analysis of brown coal are related to lithotype [George, 1975]. Volatile matter, carbon and hydrogen all tend to increase from dark through to pale lithotype while oxygen shows a tendency to decrease. These trends are to a large degree related to the fact that the liptinite macerals, which show a proportionate increase in abundance towards the lighter lithotypes, are higher in volatiles, hydrogen and, to a lesser degree, carbon, than macerals of the huminite group. This results in oxygen, which is determined by difference, showing a corresponding general decrease.

Specific Energy is also considered a chemical property of brown coal. Net Wet Specific Energy is inversely related to moisture content while Gross Dry Specific Energy is largely a function of coal type and shows an increase from dark through to pale lithotype coals [Kiss 1982]. This variation is further explored in Section 6.

In terms of the non-organic chemistry, mineral matter in brown coal is primarily of epigenetic origin and thereby bears no particular relationship to lithotype. The inorganic constituents also appear to be generally unrelated to lithotype, with no evidence of consistent concentration changes across lithotype boundaries [Kiss 1982]. The non-organic chemistry of Latrobe Valley brown COAL has already been outlined in Section 2.3.2.

5 MOISTURE VARIATION IN BORE 3651 N

5.1 Moisture and Lithotype

The results of this investigation are summarised in Figure 8. The variation of moisture with depth is plotted alongside the corresponding lithotype logs and the percentage ash (dry basis) is included to demonstrate that no coal sample is grossly contaminated with minerals or inorganics and that ash yield is unrelated to lithotype. The bar chart indicating percentage free wood shows which samples are particularly woody. Before studying Figure 8 in detail, it must also be noted that the slight increase in physical rank from the top to the bottom of the column represented is likely to result in a lowering of moisture, probably of around 0.5% to 1.0%. Such trends are subject to local variations and are, therefore, difficult to quantify over a relatively short interval such as this.

The major feature of the bed moisture distribution is the presence of large, abrupt changes from one sample interval to another. Examples of this occur at about 14 and 20 metres depth where pronounced low moisture values coincide with bands of light and pale lithotype coal and at around 11 and 21 metres depth where samples high in both moisture and wood content occur. Apart from these observations, however, Figure 8 does not suggest that a really strong relationship exists between moisture and lithotype or moisture and wood content.

Figure 9 shows moisture and colour index plotted against depth. These plots suggest there is an inverse relationship between these parameters, i.e. the lower colour indices (darker lithotypes) tend to correspond with higher moisture content and higher colour values with lower moisture.

This effect is more pronounced at depths below 10 metres, although there are noticeable distortions, mainly the samples with higher wood content, as noted above.

Table 5 lists average moisture values for the visually determined lithotypes in Bore 3651 N

TABLE 5

AVERAGE MOISTURE VALUES FOR EACH LITHOTYPE

LITHOTYPE	NUMBER OF SAMPLES	AVERAGE MOISTURE
Dark	2	65.9
Medium Dark	13	66.2
Medium Light	27	65.4 (65.3)*
Light	6	64.8 (63.7)*
Pale	2	61.7

* The figures given in brackets indicate average moisture with the two high wood/high moisture samples at around 11 and 21 metres depth deleted from the data.

The data in Table 5 show that moisture is lower in the lighter lithotypes. The apparent reversal of such a trend shown by the dark lithotype is not significant, particularly as only two samples, at the very top of the recovered core, are categorised as dark lithotype.

In addition to this, the colour index values suggest that these two samples are only marginally darker than much of the medium dark coal in the rest of the core, an impression also gained during visual logging. It is, therefore, obvious that this study is lacking an adequate representation of truly dark lithotypes, a situation that arose when it proved impossible to core the top four metres of the bore, which were known to contain more dark lithotype.

The overall relationship between moisture and lithotype is depicted graphically in Figure 10.

Here again, the broad relationship of moisture to lithotype is evident, even though the data points are fairly widely spaced. In this and similar figures, the correlation coefficient r and the significance probability p (see Appendix 2) are listed in order to furnish comparative data and give some indication of the degree of correlation. Figure 11 shows the slightly lower but equally significant correlation between moisture and colour.

5.2 Moisture and Petrography

A relatively high degree of correlation exists between moisture and two particular maceral groups, humotelinite and liptinite (Figures 12 & 13).

The content of humotelinite is known to be related to lithotype, as in the Yallourn Seam it comprises around 25% of the dark lithotype coal and decreases through the range of lithotypes to less than 3% for pale lithotype coal [George 1972, 1975]. The correlation between moisture and humotelinite (r = 0.69, Figure 12) is, however, significantly greater than that for moisture and lithotype (r = 0.53, Figure 10) or for moisture and colour index (r = 0.45, Figure 11). This observation will be further discussed in Section 5.4. It should also be noted that the correlation between moisture and texto-ulminite is slightly higher than for moisture and humotelinite (r = 0.72, Appendix 2). This is only a marginal increase however and it is noted that texto-ulminite is in this study by far the dominant maceral of the humotelinite group (Appendix 6.3).

5.3 Moisture and Wood Content

The two abrupt, high moisture peaks shown in Figures 8 & 9 coincide, as mentioned in Section 5.1, with the two highest estimated percentages of free wood content (Appendix 4). For the remaining samples, however, all with an estimated free wood content of 30% or less, the relationship between the two parameters is less apparent. This is illustrated in Figure 14.

Although a statistically significant correlation is indicated, deletion of the two highest estimated free wood samples (48 & 17) from the data results in a sharp reduction of r to 0.19 (Appendix 2) with p consequently becoming 0.1, i.e. the correlation is no longer significant. Thus for the main part, little correlation seems to exist between estimated free wood and moisture where the amount of wood present comprises less than about one-third of the coal mass.

The percentage humotelinite is largely a measure of the total amount of cellular plant tissue recognisable in the coal. It, therefore, provides an indication of the amount of woody material present on both the macroscopic and microscopic scale. As shown in Figure 15, the relationship between estimated free wood and humotelinite displays a significant degree of correlation with $r = 0.89$.

The relationship between moisture and humotelinite has already been outlined in Section 5.2 and it is noteworthy that moisture shows a higher degree of correlation with humotelinite ($r = 0.69$, Figure 12) than with estimated free wood ($r = 0.49$, Figure 14).

5.4 Analysis

In examining the way in which bed moisture varies with lithotype and coal petrology, this study has suggested that moisture correlates significantly with lithotype but shows a higher degree of correlation with the maceral groups humotelinite and liptinite. The relationship between bed moisture and estimated free wood is probably not significant.

Before attempting to interpret these observations, it is necessary to appreciate that the moisture content of raw brown coal is a direct function of available pore space and in a bed moist condition it is assumed that all pores within the coal structure are completely water filled [Allardice et al 1977]. Accordingly, the observed high bed moisture content of Latrobe Valley coals shows their physical structure to have a high voids to solid ratio. In coals of the Latrobe Valley type, the pore space available is largely determined by the physical rank of the coal, which reflects the degree of compression to which it has been subjected. In general, the higher the rank of the coal, the lower will be the bed moisture content [George 1975].

The volume occupied by the water in bed moist coal, if expressed as a percentage of the volume of the bed moisture and the associated coal substance, is referred to as the 'bed moist porosity' [Allardice et al 1977]. Bed moist porosity is calculated from the helium (true) density and bed moisture content and should not be confused with the more commonly used parameter of porosity. Porosity is derived from helium and mercury (apparent) density determinations carried out on completely dried samples which have already undergone shrinkage during desiccation and have consequently suffered a reduction, to varying degrees, in the volume of pore space.

Allardice et al (1977) have demonstrated that bed moist porosity shows a general increase from pale through to dark lithotype. This parallels a similar trend for bed moisture [George 1975, Kiss & King 1977, SECV 1980] and it seems likely that both bed moisture and, therefore, bed moist porosity are related to the micropetrographic structure of the coal, which in turn is a function of lithotype [George 1982].

Humotelinite in the form of textinite and texto-ulminite consists essentially of a 3-dimensional latticework of cell lumens with an inherently high voids to solids ratio (see Photomicrographs 11, 15, 17 to 28, Appendix 10). The potential for much of the humotelinite in coal to act as an efficient reservoir for moisture is, therefore, high. As the content of humotelinite also shows a marked increase from pale through to dark lithotype [George 1982], it is apparent that a relationship exists between lithotype, humotelinite and bed moisture so that each of these variables also relates to bed moist porosity.

It is noted that the results of this particular study suggest that relatively high humotelinite values are shown by some of the lighter lithotypes (Appendix 6). This should not be interpreted as a contradiction with the data presented by George (1982), however, as the few samples in question are woody samples atypical of the overall composition of the relevant lithotype.

The relationship between bed moist porosity and the content of humotelinite would be upset if a substantial portion of the humotelinite happened to consist of eu-ulminite, which by nature possesses a very low voids to solids ratio (see Photomicrographs 12 to 14, Appendix 10). Such an occurrence is not shown by this study or others since textinite and texto-ulminite normally comprise the major part of humotelinite, even when gelification is well advanced as in some of the darker lithotypes [George 1975, SECV 1980].

The correlation between liptinite and moisture content (Figure 13) is almost as high as for humotelinite and moisture even though liptinite in itself is not likely to substantially affect bed moist porosity. The liptinite content is, however, closely related to lithotype [George 1975], so much so that it perhaps provides a more reliable indicator of lithotype than the broad but practical classification of brown coal into five basic lithotypes. Should this be the case, it might explain why moisture correlates substantially better with liptinite than with logged lithotype. Admittedly colour index is also an indicator of lithotype but it fails to correlate as well with moisture as does liptinite. This is probably due to the fact that the determination of colour index is subject to the variables mentioned in Section 2.3.1 and can be regarded as a less direct measurement than a maceral count.

From the abovementioned relationship, it is plausible to suggest that liptinite and perhaps humotelinite are more accurate indicators of what could be described as 'true' lithotype than either lithotype as logged or derived from colour index measurements. The relationship between bed moisture and coal type might, therefore, be better defined using selected macerals or maceral groups as indicators of lithotype in preference to either the more limited scale of logged lithotype or colour index values.

As noted in Section 5.3, little discernible relationship exists between moisture and estimated free wood when the latter value is below around 30%. The reason for this probably lies partly with the fact that the content of free wood will almost invariably comprise a range of wood or xylite types showing varying degrees of infilling, alteration, structure and gelification.

More significantly, however, the method of measuring free wood (Appendix 4) was intended simply to provide an extra control on the possible reasons for anomalously high moisture values and as such it is not a precise measurement. It, therefore, cannot be regarded as being sufficiently accurate for comparison with the far more precise moisture values, at least where estimated wood is within the usual range of up to one-third of the volume of coal.

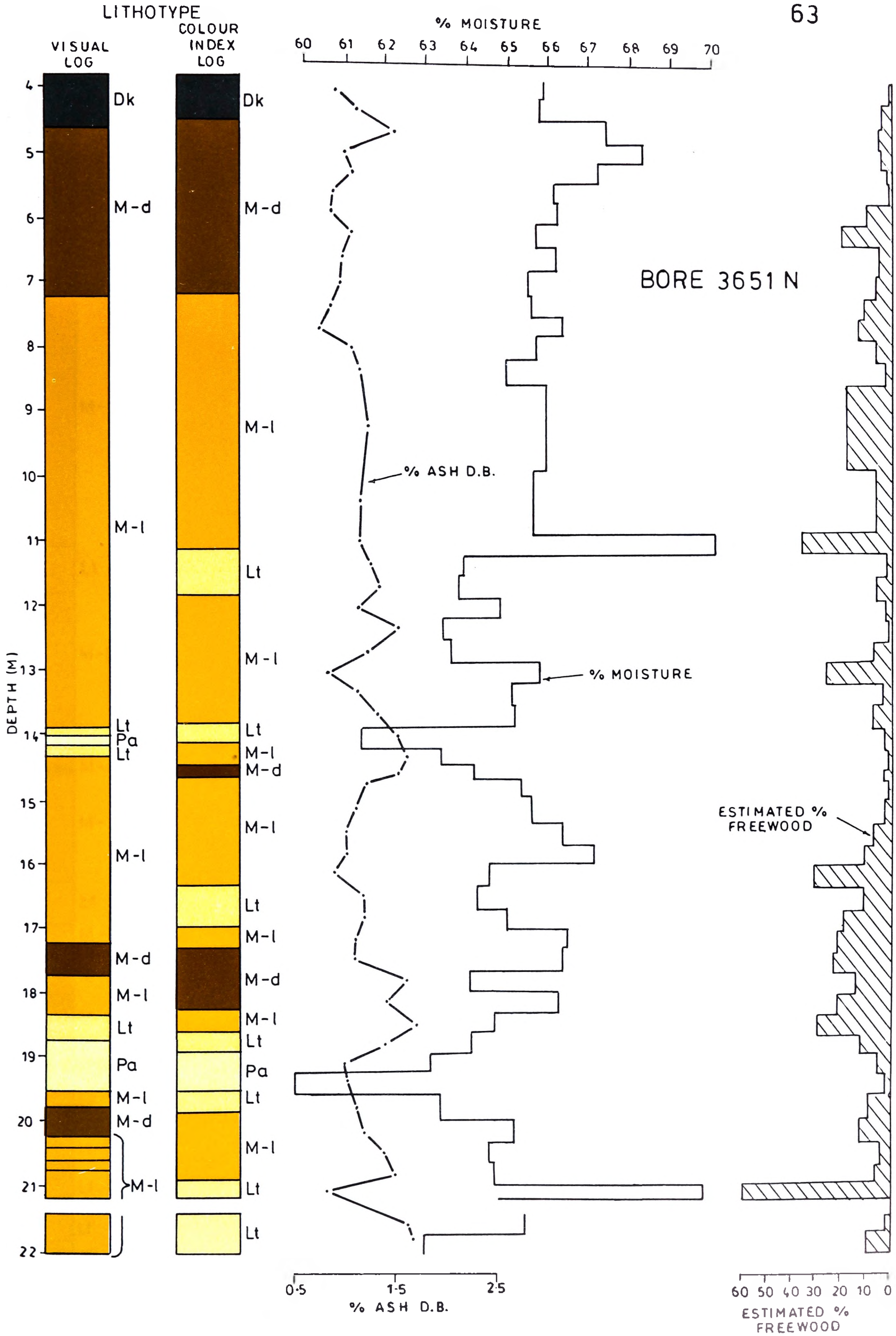


FIG 8

VARIATION OF MOISTURE ASH AND ESTIMATED FREEWOOD WITH DEPTH

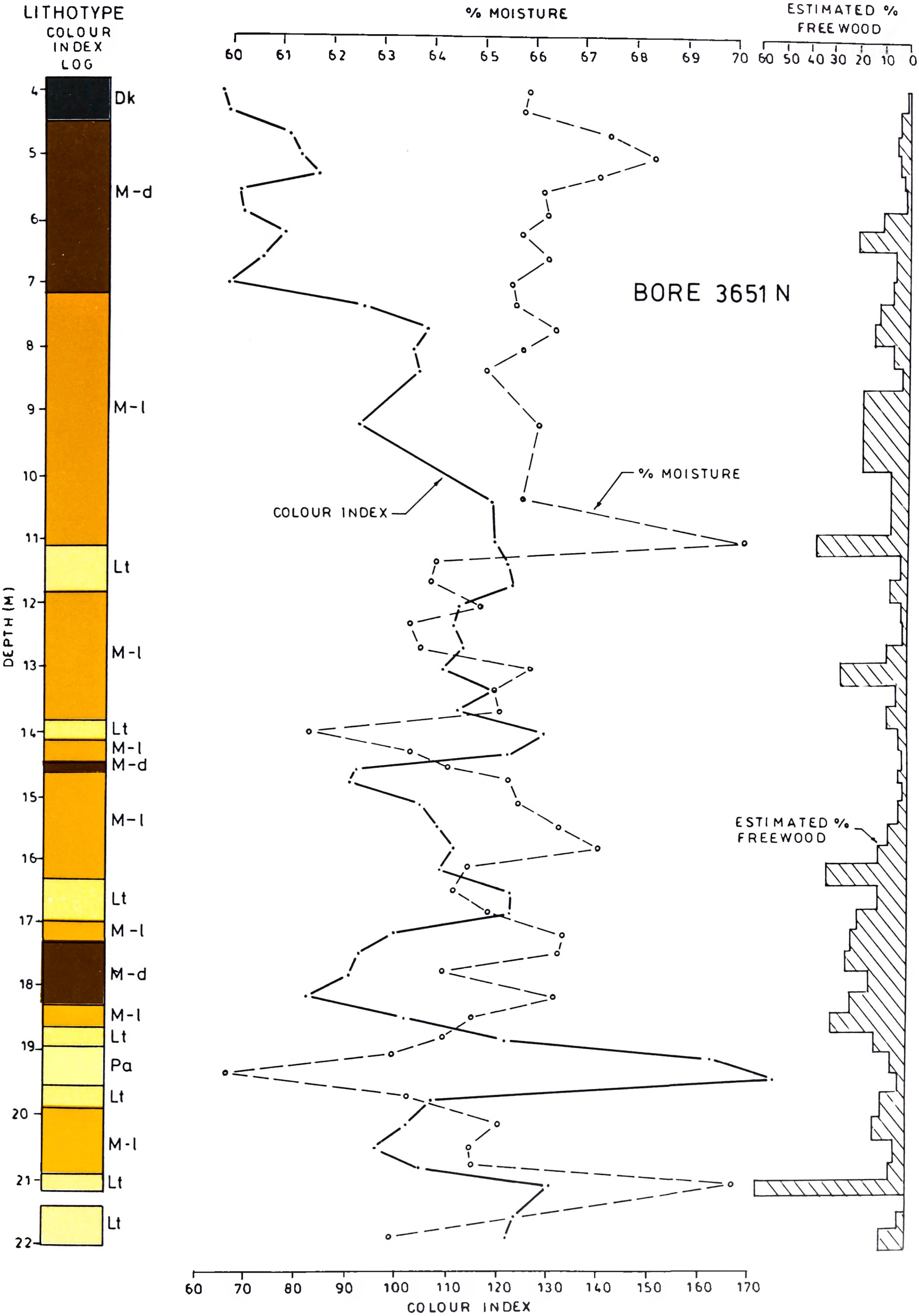


FIG 9

VARIATION OF COLOUR INDEX AND MOISTURE WITH DEPTH

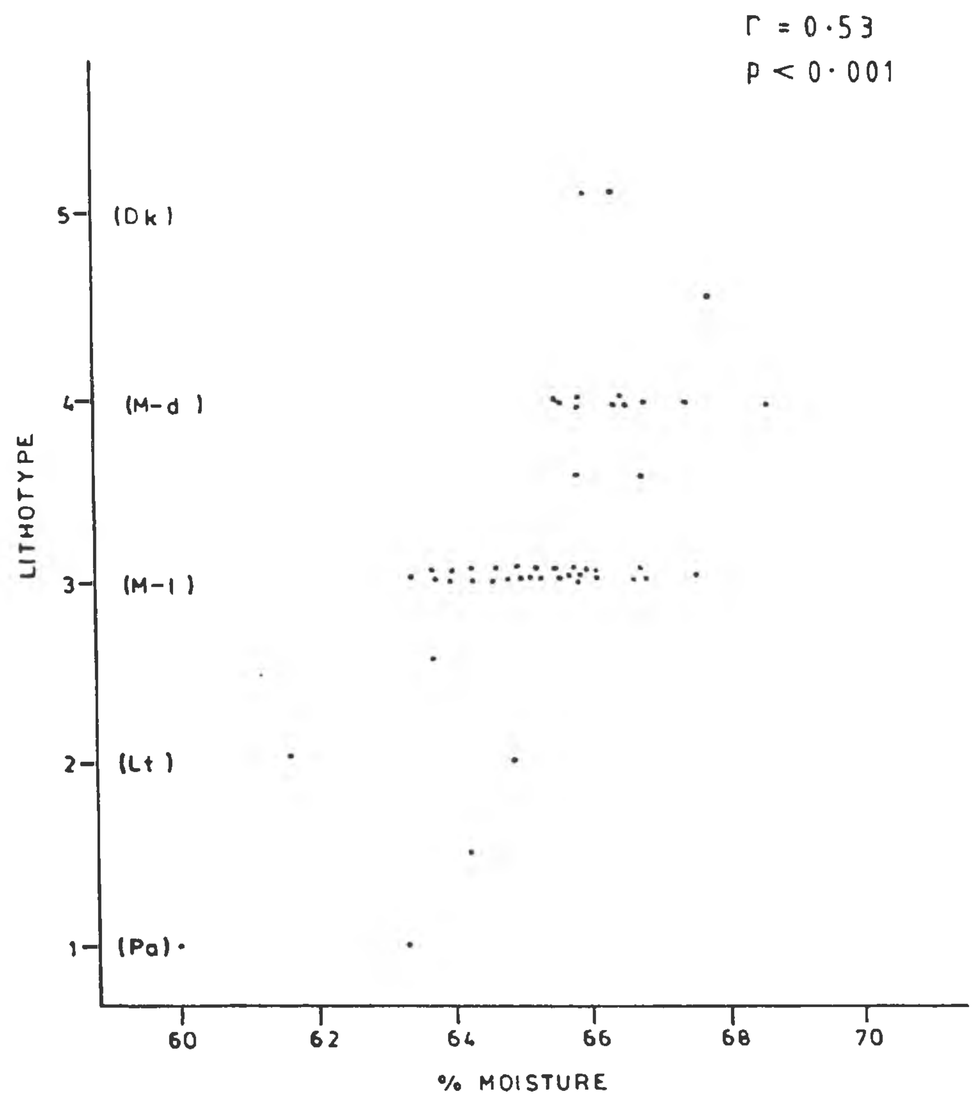


FIG 10 MOISTURE VERSUS LITHOTYPE

NOTE: The correlation coefficient (r) shown is, consistent with the other statistical analyses in this thesis, the result of a Pearson Product Moment Correlation (see Appendix 2). As it is considered that the Pearson Product Moment Correlation may be less suited to the analysis of semi quantitative data (such as the above lithotype groupings) than certain alternative models, an additional correlation coefficient was generated from the same data using the Spearman Rank method.

This resulted in a slightly higher apparent degree of correlation with $r = 0.59$.

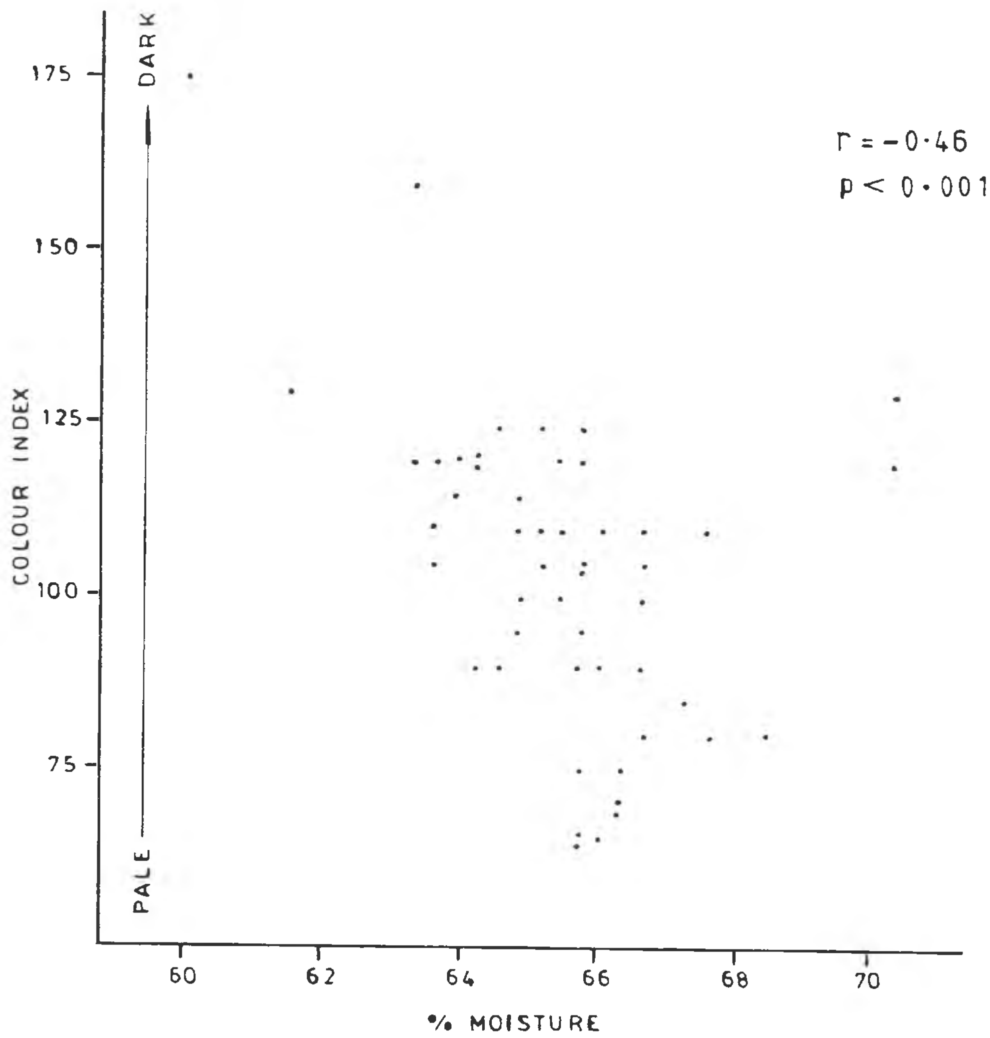


FIG 11 MOISTURE VERSUS COLOUR INDEX

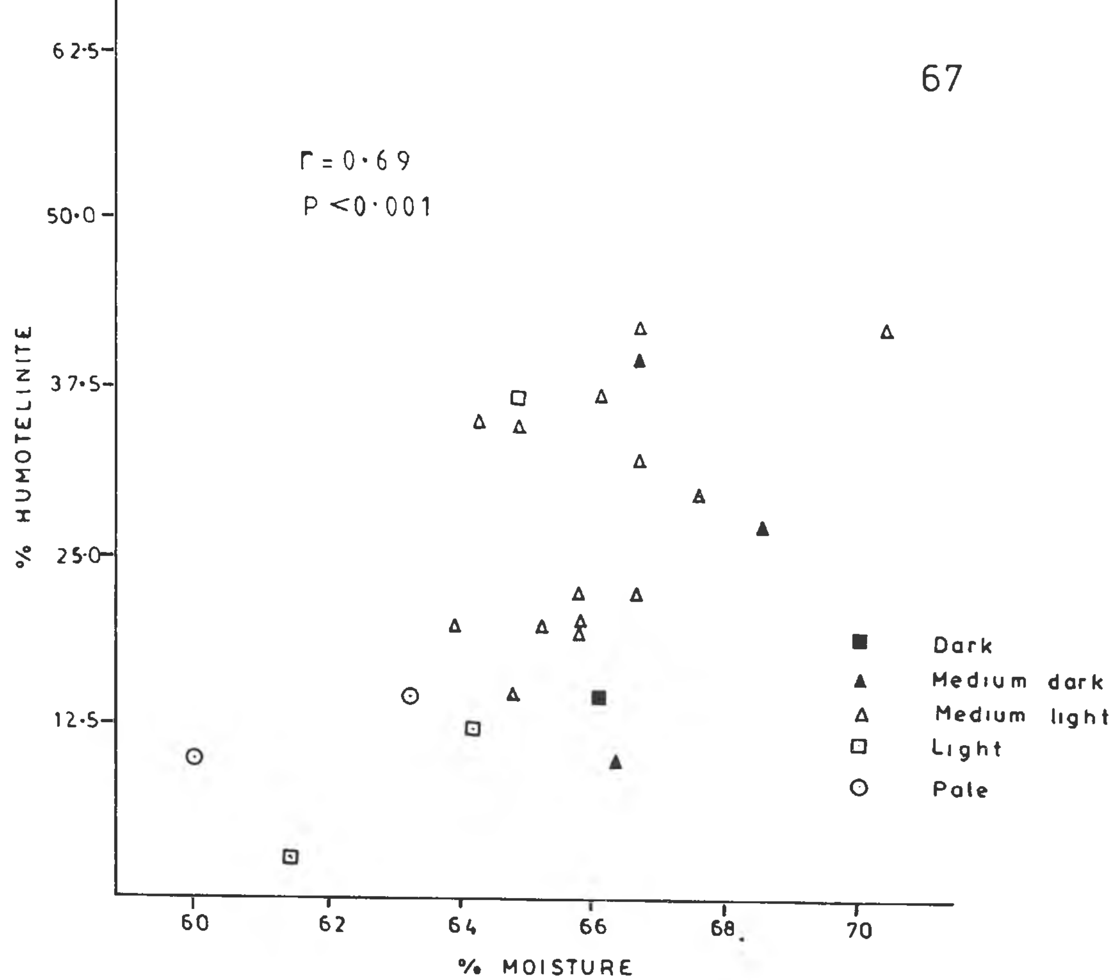


FIG 12 MOISTURE VERSUS HUMOTELINITE

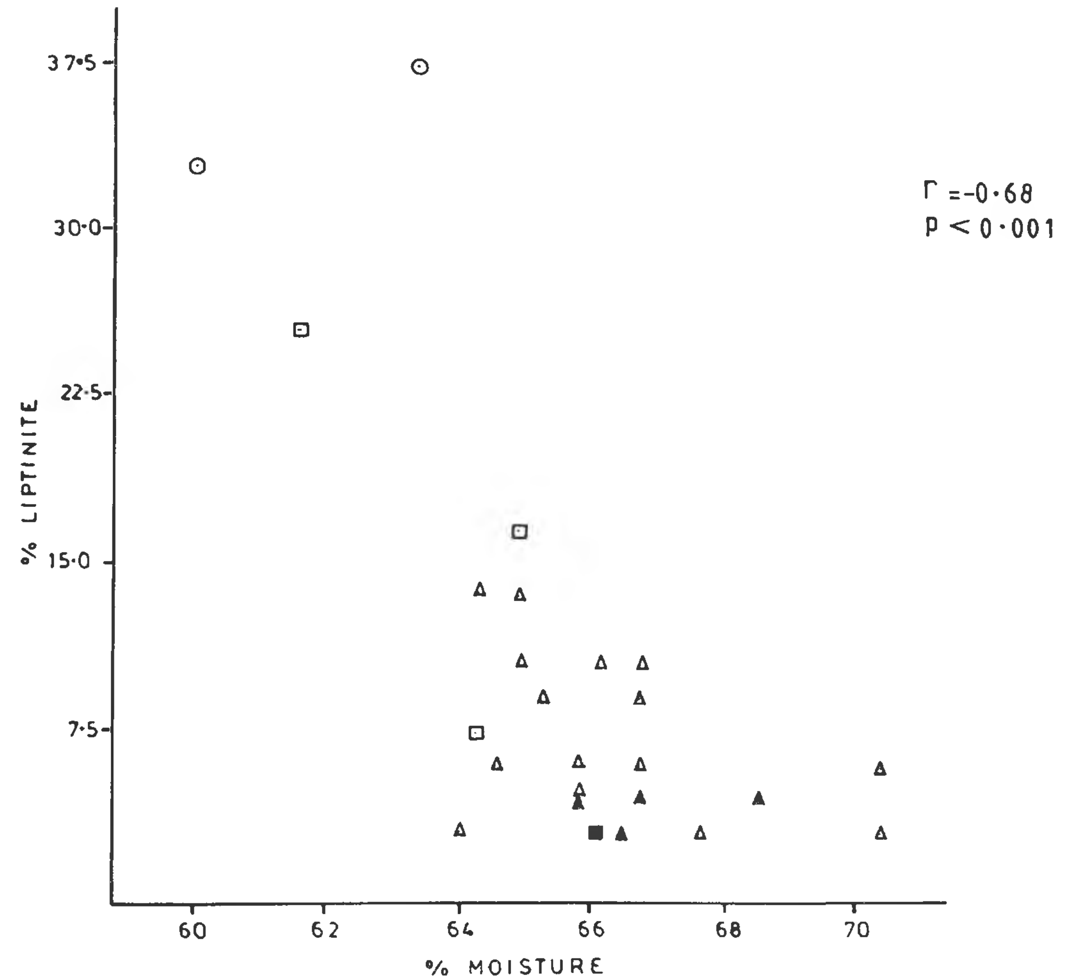


FIG 13 MOISTURE VERSUS LIPTINITE

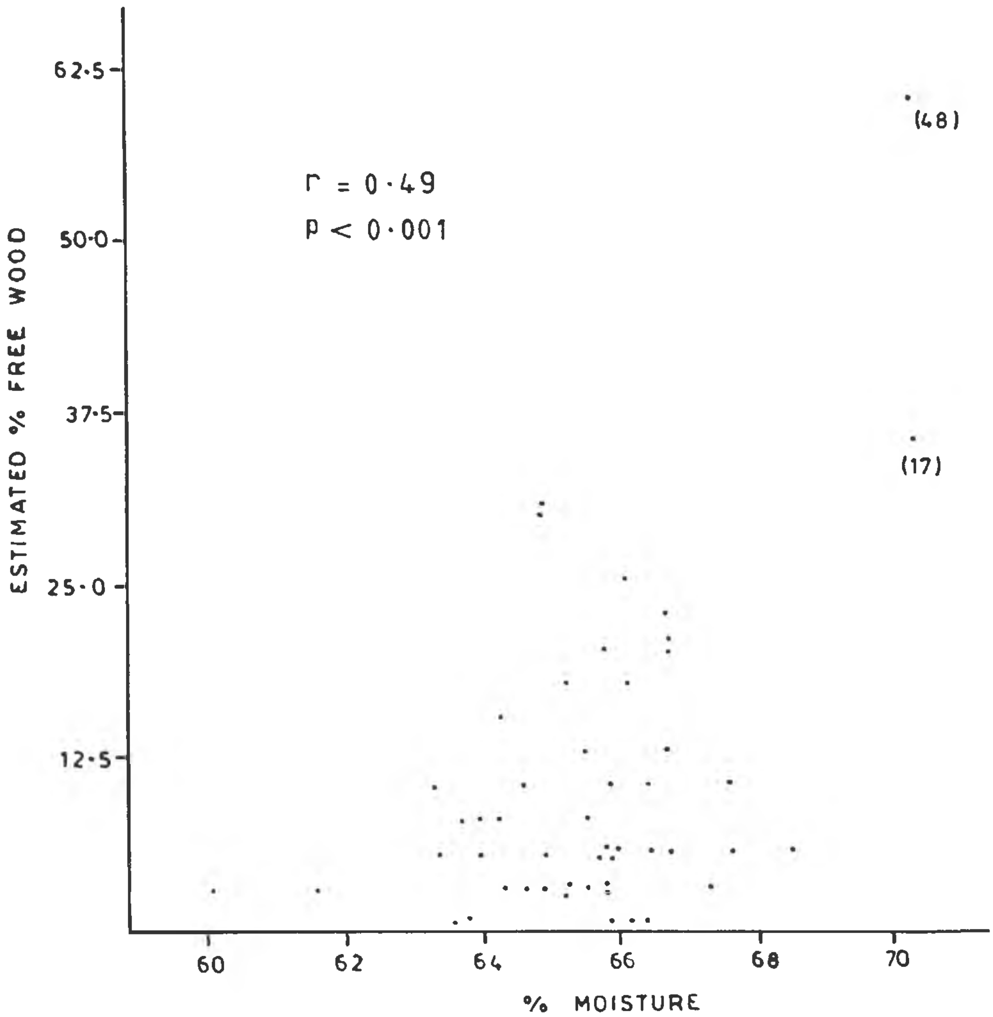


FIG 14 MOISTURE VERSUS ESTIMATED FREE WOOD

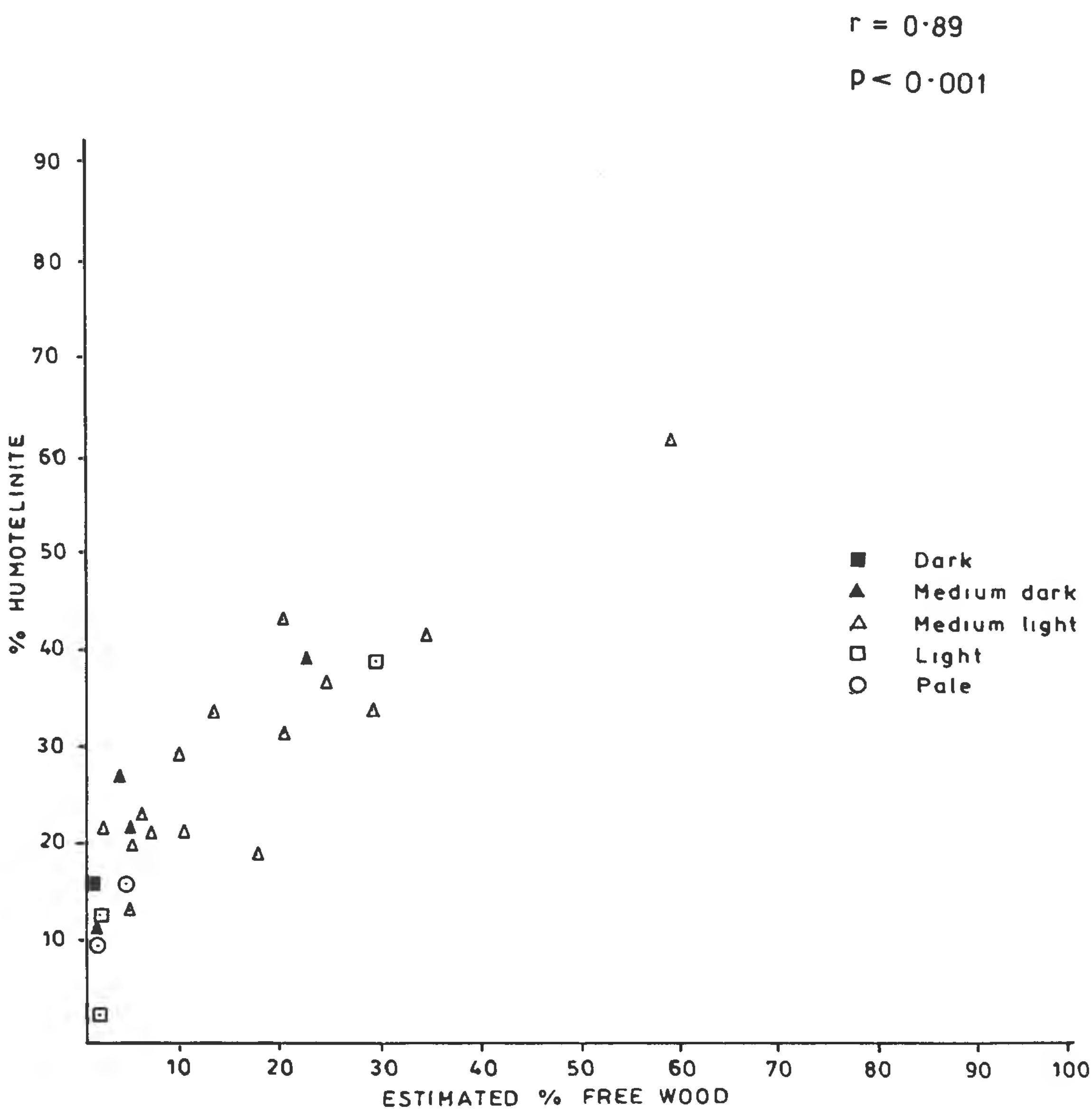


FIG 15 ESTIMATED FREE WOOD VERSUS HUMOTELINITE

6 MOISTURE AND SPECIFIC ENERGY

The net wet specific energy of brown coal is a parameter particularly relevant to coal usage in boilers as it is - by definition - the amount of energy released in a constant pressure combustion system in which all the moisture, either initially present in the coal or produced during combustion, is converted to vapour [Allardice et al 1977], i.e. it is a measure of the available energy content of the coal. Gross dry specific energy on the other hand is largely dependent on the chemical composition of the organic coal substance and is, therefore, more strongly related to the chemical substance of the coal than to its physical rank [SECV 1980].

As both net wet and gross wet specific energies are calculated from direct measurements of coal bed moisture content and gross dry specific energy, it is to be expected that the correlation between moisture content and both net wet and gross wet specific energy will be high. The relationship between moisture and net wet specific energy, for Bore 3615 N, is shown in Figure 16, while the statistically identical relationship between moisture and gross wet specific energy is shown in Figure 17. The notably poorer relationship between moisture and gross dry specific energy is demonstrated in Figure 18, while Figure 19 illustrates the inverse relationship between moisture content and net wet specific energy when both are plotted against depth.

Some indication of the significance of the relationship between moisture and net wet specific energy is given by Kiss (1982(a)) who reports that a variation in moisture content of less than 3% in coal excavated from the Yallourn Seam can cause a loss of output of up to 30% in a large thermal power station.

In considering this observation, it should be realised that for coal samples in the usual (60-70%) moisture range, the percentage moisture (as received) is derived from the weight of water over the weight of water plus coal substance. If the moisture (as received) values are compared with the moisture percentage on a dry basis (weight of water over weight of coal substance only x 10^2 - see also Appendix 6.1), it becomes clear that a small increase in moisture (as received) can signify a proportionately much higher increase in moisture expressed on a dry basis, thereby indicating a significant increase in the actual proportion of water in relation to coal substance.

A much lower but still significant correlation is also shown between moisture and gross dry specific energy ($r = -0.44$, Figures 19 & 20).

As is apparent in Figure 20, the gross dry specific energy shows only a partial inverse relationship to moisture, the major departures from mirror image plots coinciding with samples containing high moisture and a large amount of free wood. High gross dry specific energies are shown in the light and pale lithotype coal samples, these being due largely to the inherently higher hydrogen and lower oxygen content of the lighter lithotypes [Allardice et al 1977]. Gross dry specific energy is thus in part a function of lithotype and this study shows that gross dry specific energy correlates better with lithotype (r = -0.72) than with either net wet specific energy (r = -0.65) or gross wet specific energy (r = -0.66) (Appendix 2).

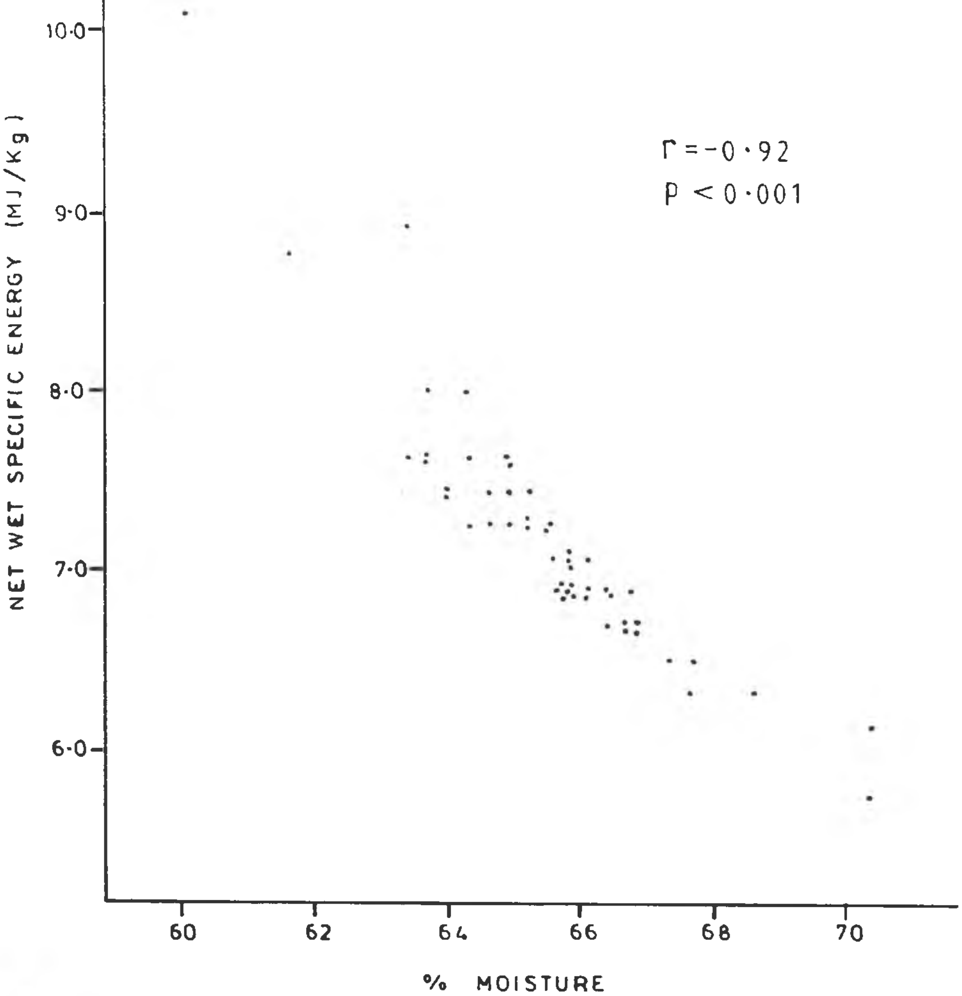


FIG16 MOISTURE VERSUS NET WET SPECIFIC ENERGY

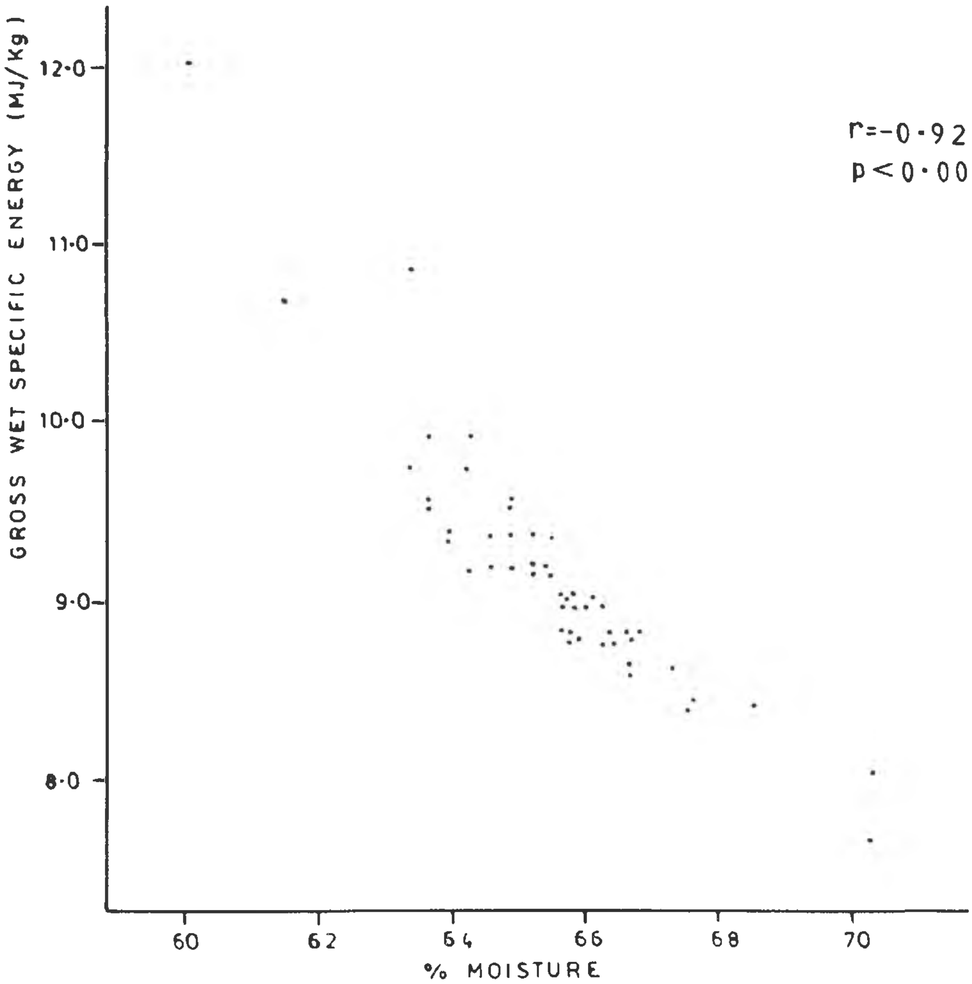


FIG17 MOISTURE VERSUS GROSS WET SPECIFIC ENERGY

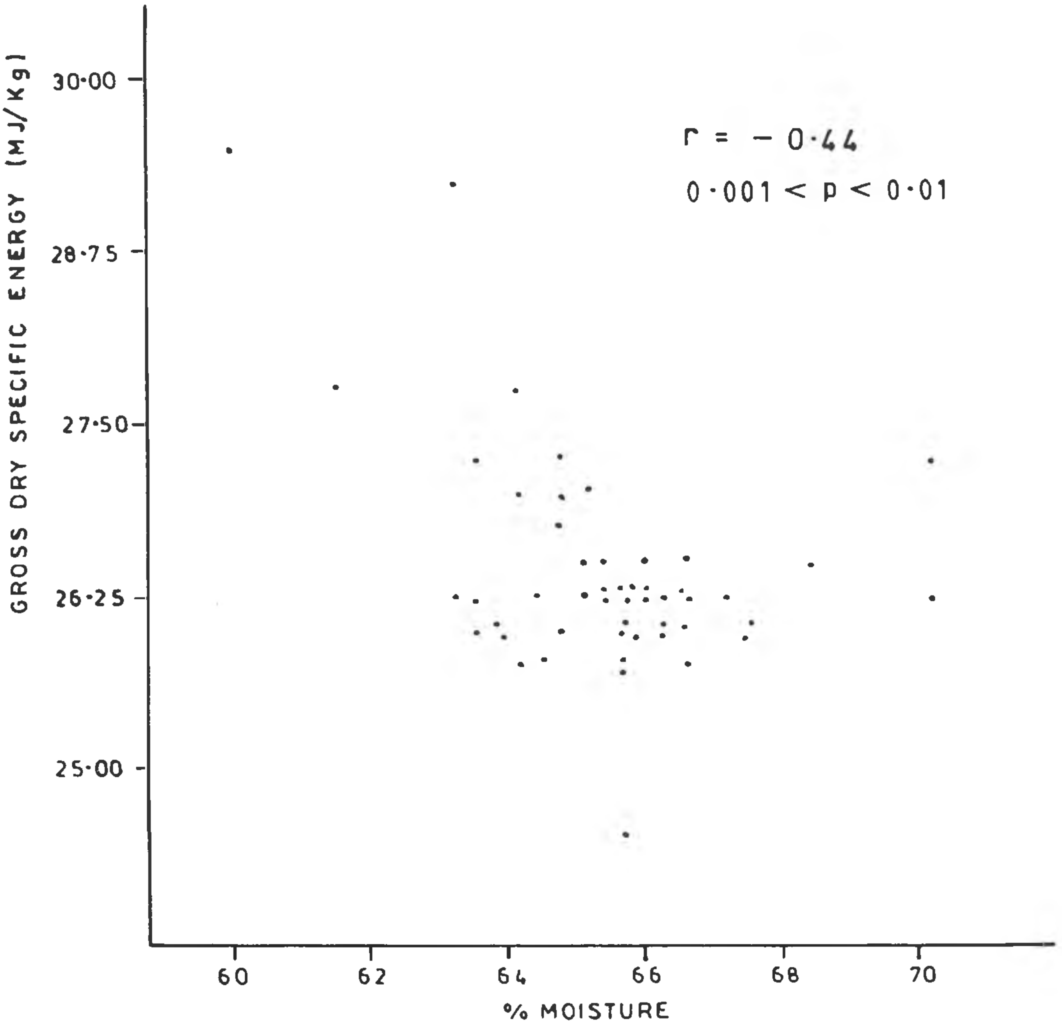


FIG 18 MOISTURE VERSUS GROSS DRY SPECIFIC ENERGY

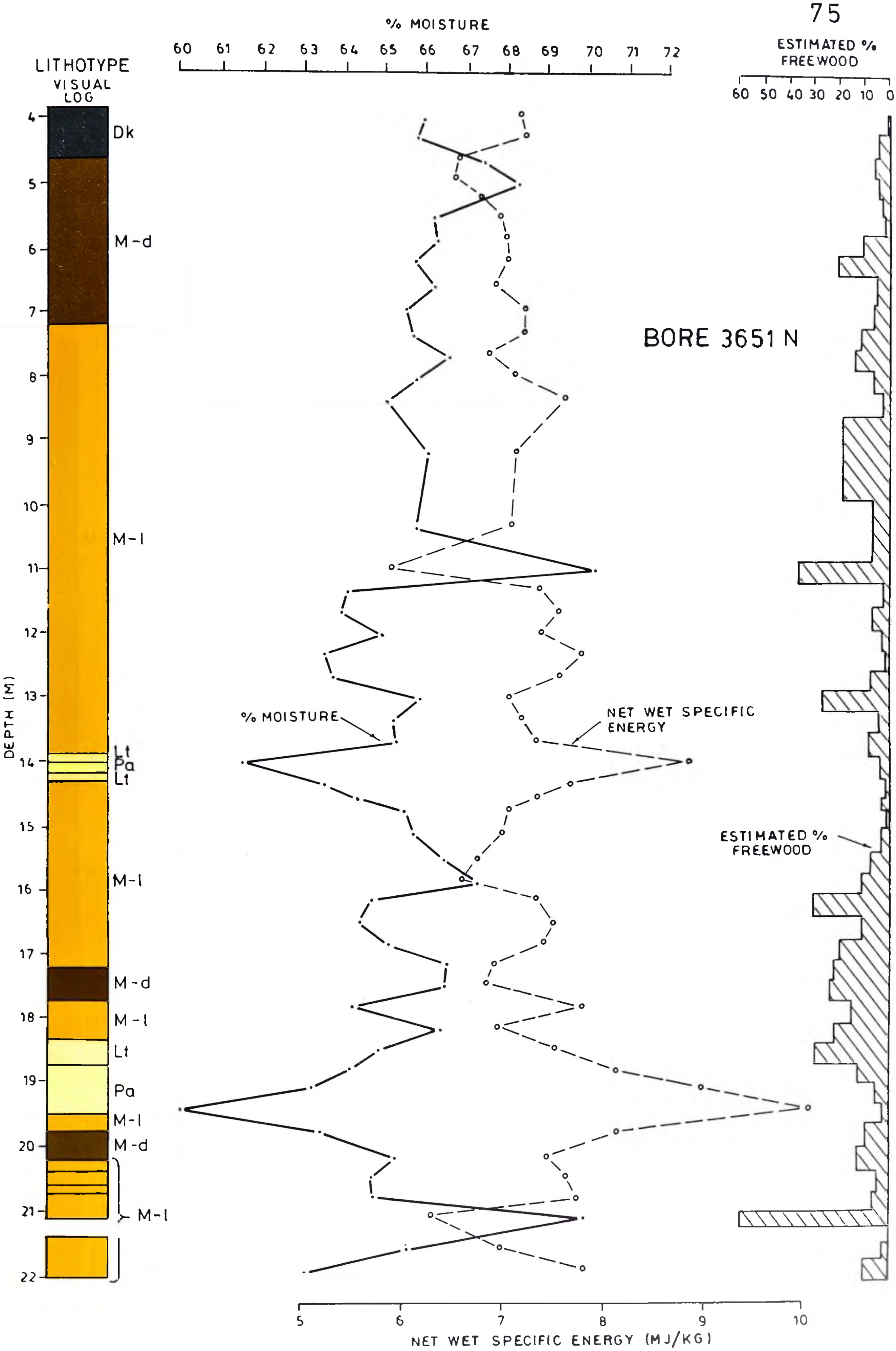


FIG 19

VARIATION OF MOISTURE AND
NET WET SPECIFIC ENERGY WITH DEPTH

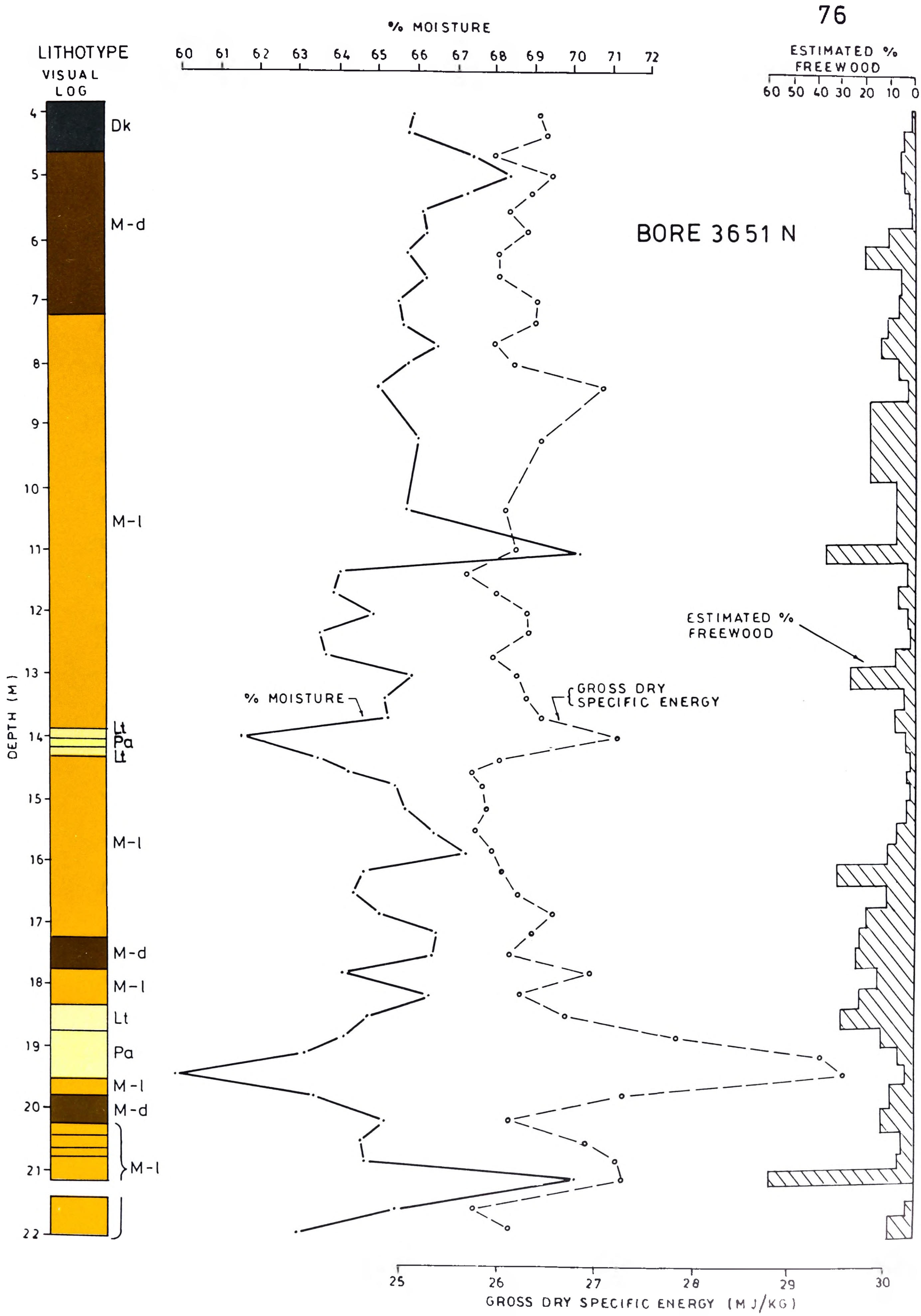


FIG 20

VARIATION OF MOISTURE AND GROSS DRY SPECIFIC ENERGY WITH DEPTH

7 SOME RELATIONSHIPS WITH CONTENT OF NITROGEN

7.1 General

As mentioned in Section 2.3.2, nitrogen determinations were carried out on a number of samples primarily to check an observed trend that the content of nitrogen in brown coal is inversely related to the amount of woody material present. Such a trend is confirmed by the results of this study and it was also noticed that nitrogen shows an unexpectedly high degree of correlation with various of the inorganic constituents. Discussion of these observations forms the basis of this section.

7.2 Nitrogen and Woody Material

The analytical results indicate that nitrogen content is strongly and inversely related to wood content represented as either measured humotelinite or estimated free wood (Figures 21 & 22). The underlying reason for this is that cellulose, which comprises much of the residual woody tissue, is essentially free of nitrogen within its organic structure, whereas the humic matrix (groundmass) of the coal contains nitrogen within the various amino acid derivatives and complex proteins present.

This is recognised by Francis (1961, pp 206-213) who reports that various investigations into the nature of humic gels and acids have led to the general conclusion that nitrogen in peat is likely to be present in the form of stabilised organic protein complexes and/or amino acid derivatives. In particular, Francis (pp 290-293) presents the results of some ultimate analyses performed on Victorian brown coals from the Bacchus Marsh area, which are similar in composition to Latrobe Valley brown coals. These coals were separated using a 'rational analysis' process into residual matrix (groundmass) and woody tissue fractions. The comparative analyses show that the woody tissue fraction displayed less than half the nitrogen content of the matrix fraction.

The high degree of correlation between nitrogen and wood content shown by the results of this study strongly suggests that nitrogen content is a useful indicator of the total amount of residual woody or cellulosic material present in the coal. This premise is, however, based on a limited number and range of samples and further investigations to evaluate any possible effects due to other variables such as wood type or the degree of gelification present would be useful.

7.3 Nitrogen and the Inorganic Cations

It was explained in Section 2.3.2 that the inorganic constituents of brown coal comprise a group of water soluble salts extractable and/or exchangeable using dilute hydrochloric acid. As such, the inorganic cations can be considered as mobile, epigenetic constituents of the coal, having been introduced as solutions in diffusing groundwaters. With the exception of dissolved $NaCl$, these inorganics eventually become bonded to free carboxylate ($-COO^-$) groups as salts of carboxylic acids [Kiss & King 1977]. As given in Section 2.3.2, the inorganics are defined in terms of chemical analysis as -

$$\text{Inorganics} \equiv \text{Na} + \text{Ca} + \text{Mg} + \text{Fe (Al)} + \text{(Si)} + \text{NaCl}.$$

The amount of carboxylate (as carboxylate salt equivalent) present is derived as the difference between the total carboxylic acidity of the coal and the free carboxylic acidity. The concentration of carboxylate groups thus obtained shows an excellent correlation with exchangeable cations [SECV 1978], thereby lending confirmation to the established concept that the inorganics are present largely as bonded salts of carboxylic acids [Kiss 1982]. Further to this, it is generally assumed that the ash forming inorganic constituents of the original vegetation from which the coal formed have been remobilised as a result of the prolonged percolation of groundwaters and either redistributed within the coal mass or flushed out of the coal seam altogether.

The distribution of ash forming inorganics in brown coal has been shown by Kiss (1982) to be largely uninfluenced by lithotype. This is supported by the results of this study (see Figure 8). As wood content is in part related to coal type [George 1975], it was not initially anticipated that any of the inorganic constituents would be likely to show a high correlation with nitrogen, or indeed any of the other constituents related to the organic chemistry or fabric of the coal. The results of this study indicate however that a strong correlation is present between nitrogen content and the inorganic cations calcium, magnesium and iron.

Before commencing to discuss this observation, it will be necessary to consider an apparent discrepancy which arises when the degree of correlation between these inorganics and measured wood content is studied. If nitrogen is, as suggested, a useful indicator of wood content, then it might logically be expected that the abovementioned inorganics will display a correlation with wood content that is as high as, or higher, than with nitrogen. As can be seen in Figures 25, 26 & 27 this is certainly not the case, a similar set of significant but low correlations existing for these constituents with estimated free wood (see Appendix 2). The probable explanation here is that by definition, both humotelinite and estimated free wood essentially comprise only recognisable cellular tissue or plant structures in which the cell walls remain substantially intact, normally as part of a relatively large mass of tissue. This excludes fragmentary cellulosic material existing within the coal matrix but unrecognised as woody tissue under the microscope. As nitrogen is a chemical value derived from destructive analysis of the entire coal sample, the proportion of nitrogen will reflect, inversely, the total amount of woody (cellulosic) material within the coal. Thus, nitrogen content could in some ways comprise a better indicator of the total residual cellulosic material present in the coal than either a measure of humotelinite or an estimate of free wood.

Bearing in mind the original mobility of the inorganics and their mode of introduction into the coal, variations in the concentration of inorganic constituents are likely to be influenced by some or all of the following:

- inherent permeability of the coal;
- initial relative mobility of the organics through the coal;
- original concentration of inorganics and/or their availability; and
- number of carboxylate groups available within the coal.

The inherent permeability of the coal would influence the eventual distribution of inorganics within the coal structure if, for instance, the passage of groundwater was partly impeded or diverted by the presence of woody material. This would mean that the amount of groundwater passing through the wood would be diminished in relation to the amount passing through adjacent coal groundmass, resulting in a smaller number of ions entering and being retained by the woody material. Apart from uncertainty as to whether woody tissue does in fact inhibit the flow of groundwater, it is likely that the span of geological time during which ion migration has been effective would tend eventually to balance out any such differences by using up available carboxylate groups on both the woody tissue and the groundmass alike.

The relative original mobility and possible subsequent remobility of the inorganics are unlikely in themselves to create the localised variations recorded in this study. This aspect is clearly related to the megascale distribution of the various inorganics throughout the full thickness of coal seams, where curved, relatively smooth concentration profiles, from the top to the base of the seam or vice versa, are often present for the various inorganics [Kiss & King 1977, Kiss 1982]. A similar situation will apply with regard to the original concentration of available inorganics, which should affect only the overall size of such concentration profiles. The most likely explanation for the variability of iron, calcium and magnesium which has given rise to the observed correlations with nitrogen is that the primary concentration of carboxylate groups to which the inorganic salts became attached is a function of the same processes which influence the content of nitrogen. If so, this would imply that woody tissue possesses less available carboxylate groups than the groundmass. This appears to be the case in light of recent analytical data [SECV 1984] which indicates that for some 23 pairs of woody and adjacent groundmass coal samples, the measured concentration of carboxylate groups is substantially lower in the wood tissue samples, averaging around 35% of values obtained for the groundmass samples. It seems then, that the consistently lower concentrations of calcium, iron and magnesium in woody material is due to the inherently lower availability of carboxylate groups to which the inorganics can become bonded. This results in the inverse relationships identified in this study as existing between these inorganics and the amount of woody tissue as indicated by nitrogen content.

With regard to aluminium and silicon, no comment can be made concerning the distribution of these inorganics as they were not analysed. In the case of sodium, however, the relationship to nitrogen is, unlike that for calcium, magnesium and iron, extremely low ($r = 0.03$, Appendix 2). The correlation coefficients for sodium with humotelinite and estimated free wood are generally higher, at $r = 0.11$ and $r = 0.08$ respectively, but these differences are considered non-significant at this level. The reason for this almost complete lack of correlation is that the bulk of the sodium is not present in the carboxylate bonded form but as chloride in solution within the bed moist coal. This is indicated by the overall ratio of sodium to chlorine as shown in the analytical results (Appendix 6.1).

As a result of the high degree of correlation of nitrogen with calcium, iron and magnesium, nitrogen also correlates moderately well with ash (Figure 28), of which these inorganics collectively comprise around 20% to 25% in typical Latrobe Valley brown coals.

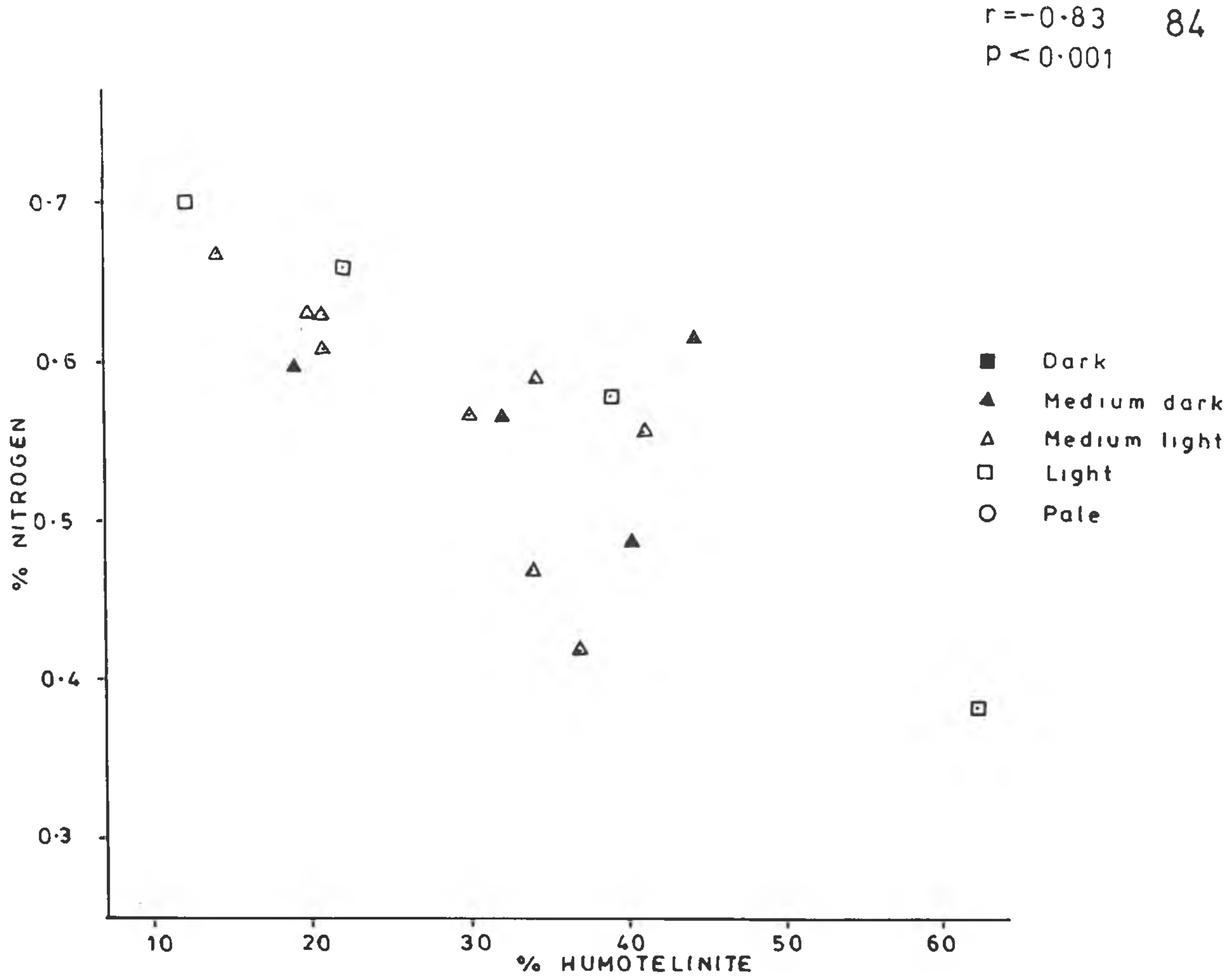


FIG 21 HUMOTELINITE VERSUS NITROGEN

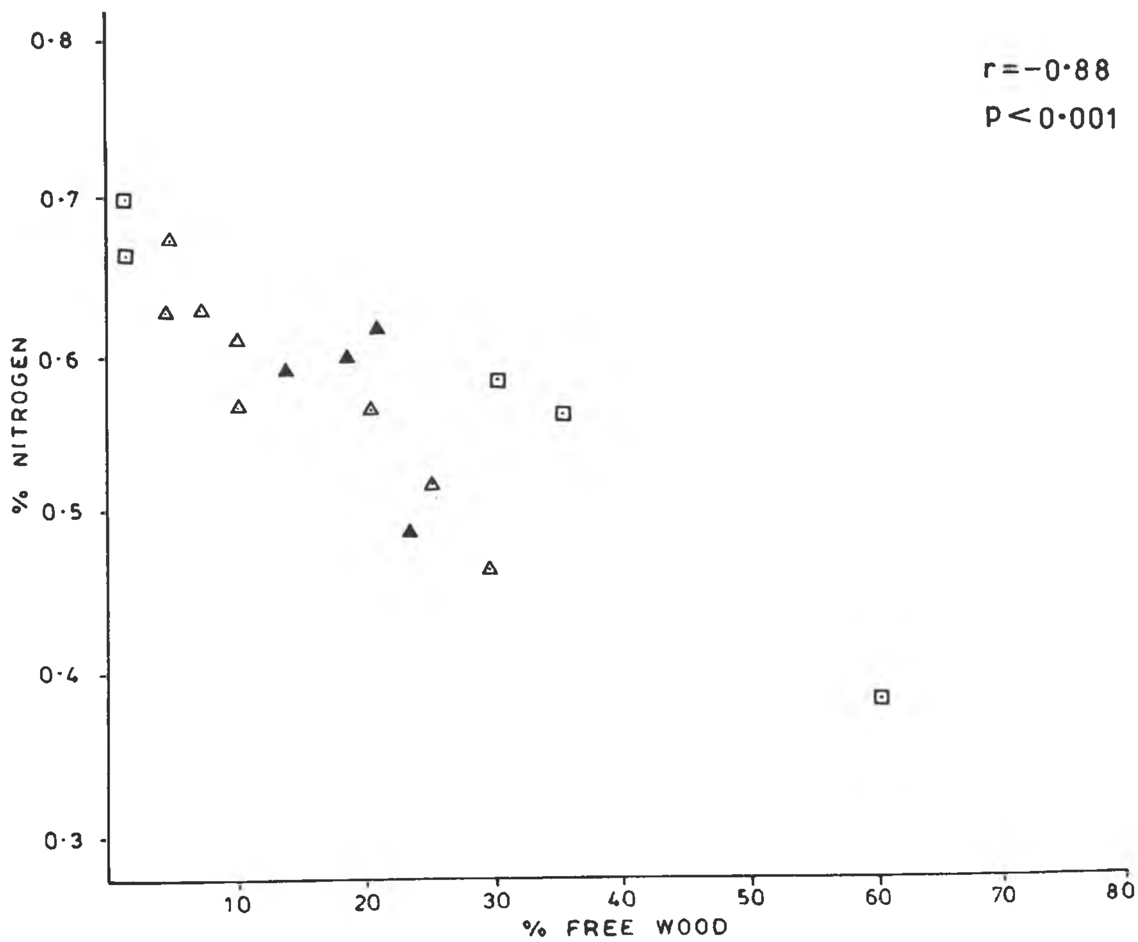


FIG 22 FREE WOOD VERSUS NITROGEN

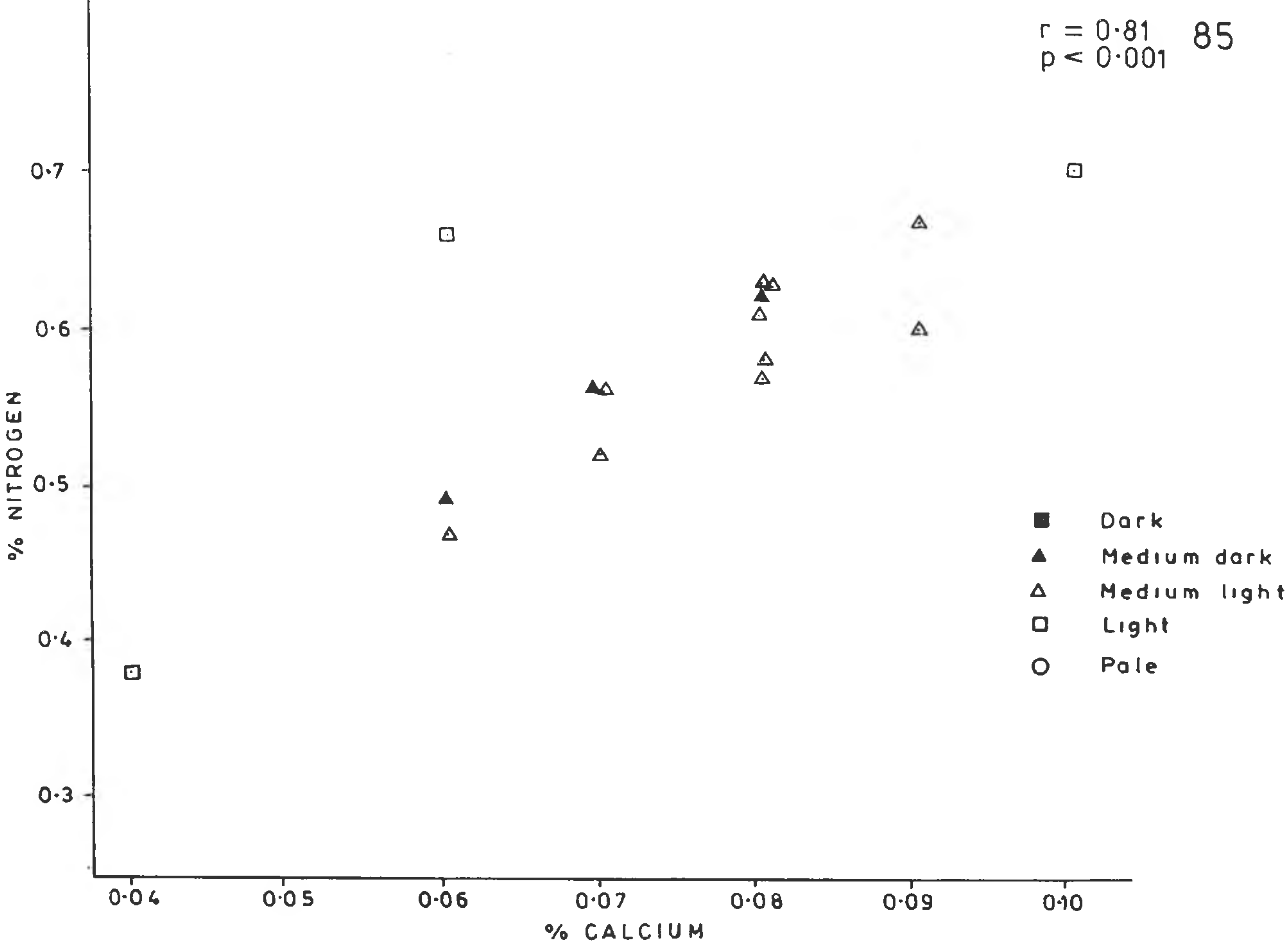


FIG 23 CALCIUM VERSUS NITROGEN

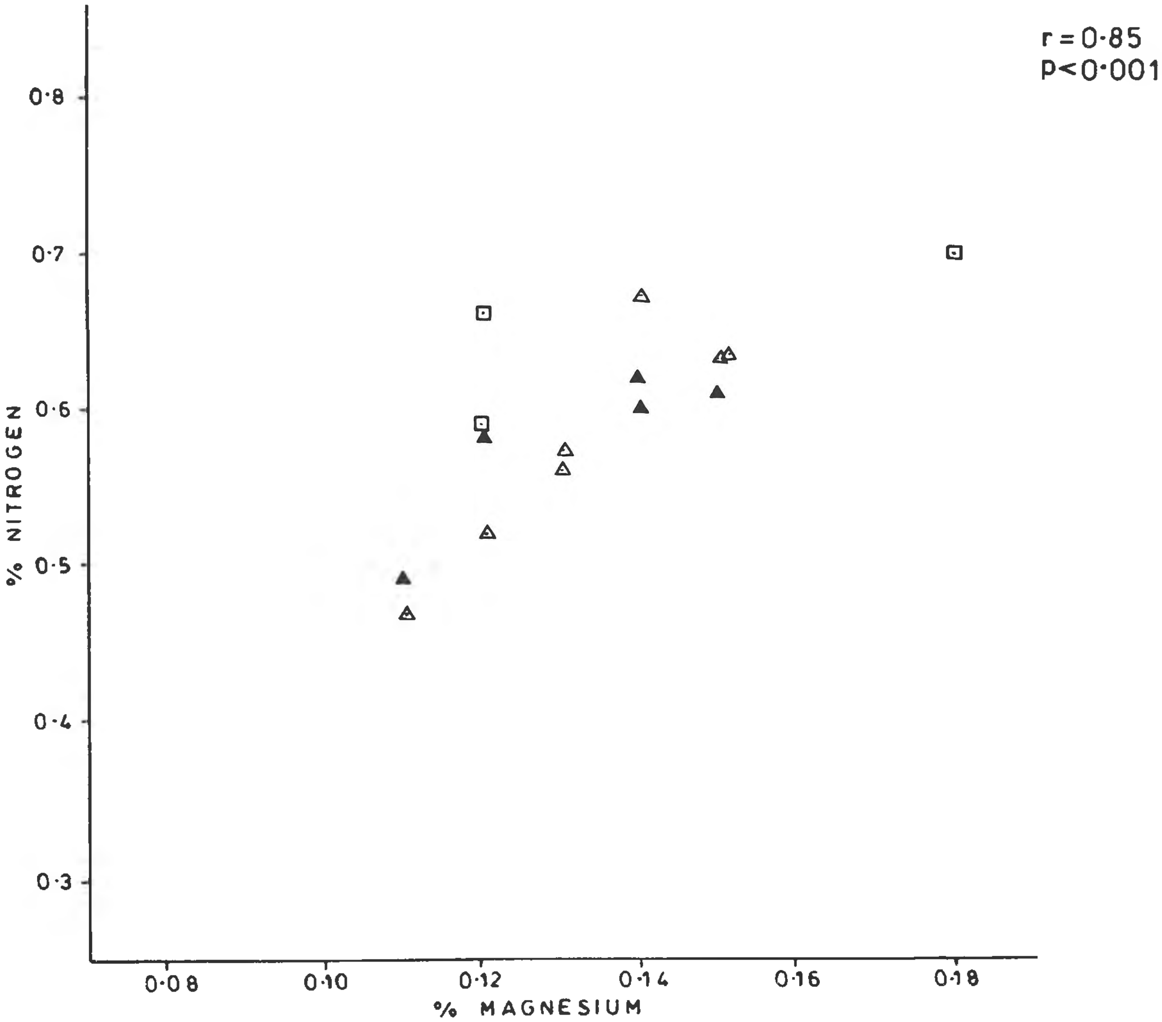


FIG 24 MAGNESIUM VERSUS NITROGEN

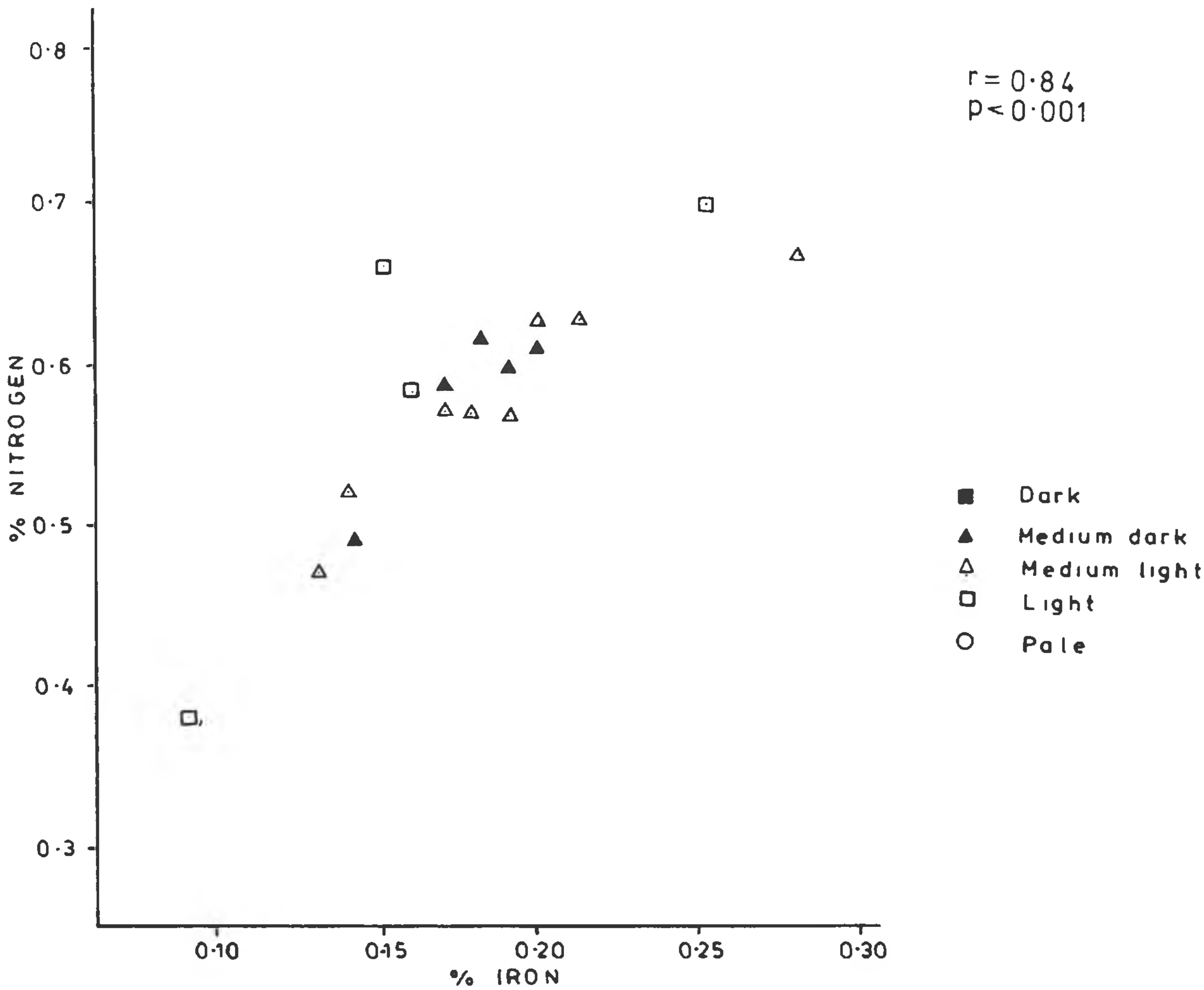


FIG 25 IRON VERSUS NITROGEN

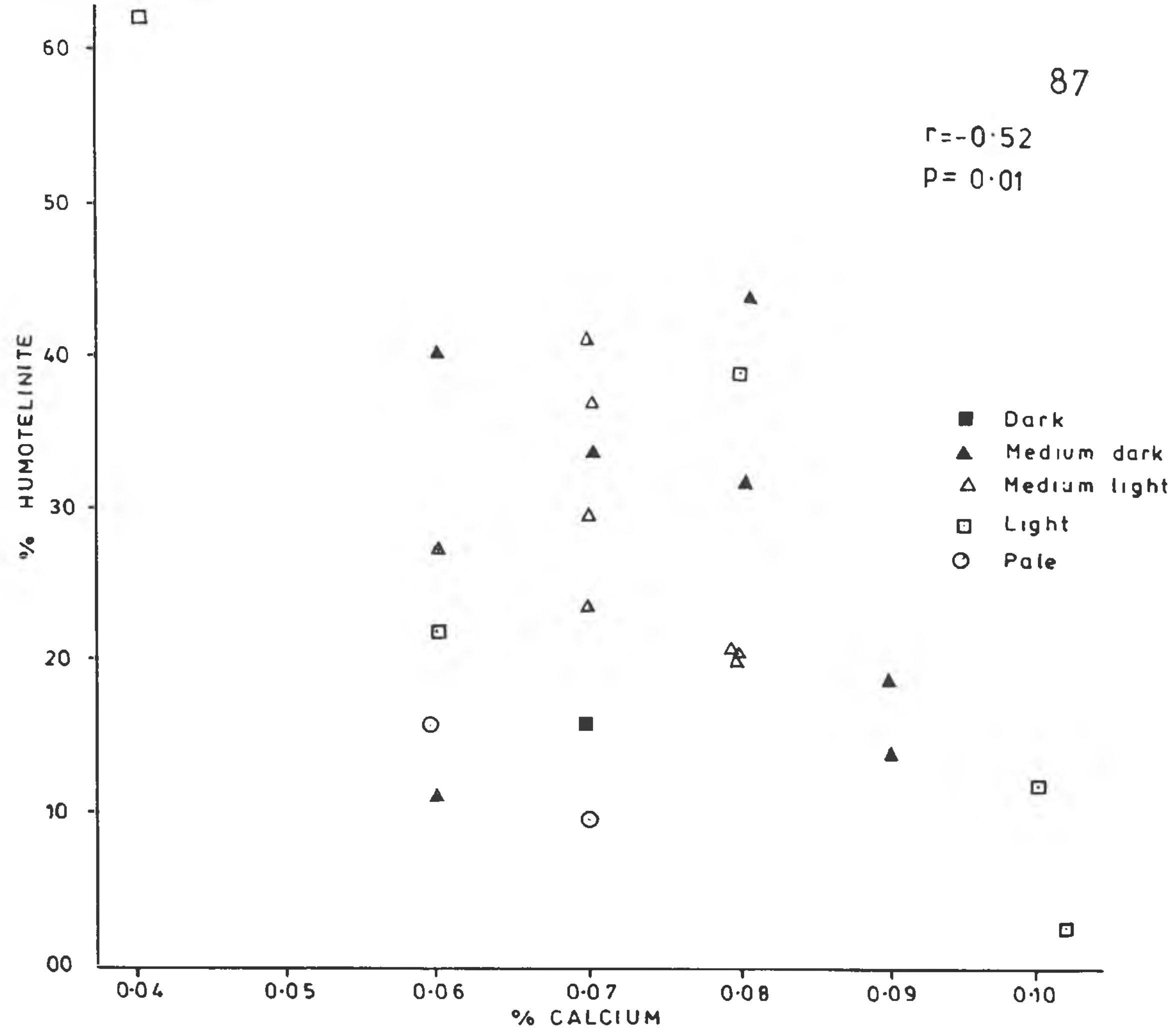


FIG 26 CALCIUM VERSUS HUMOTELINITE

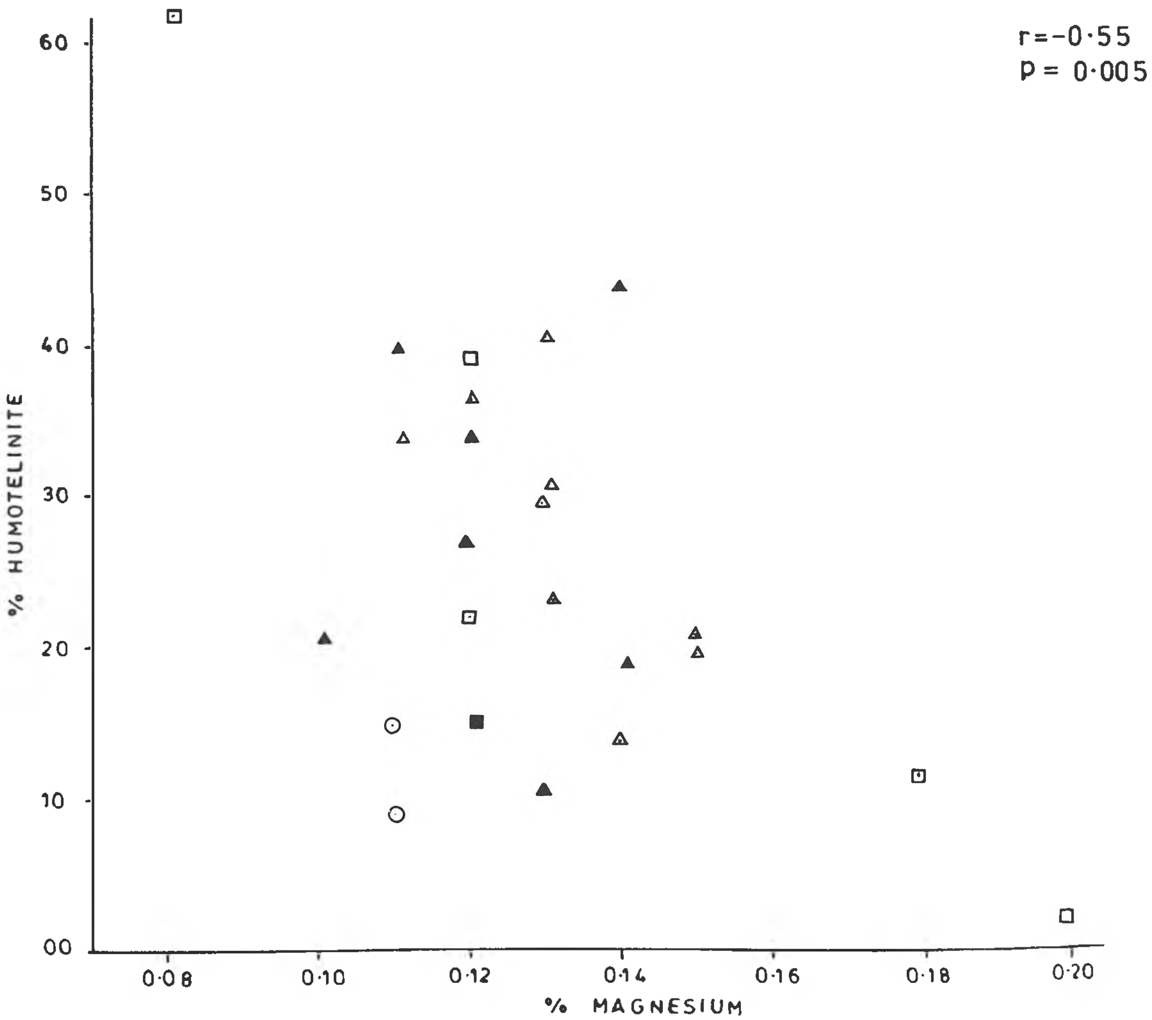


FIG 27 MAGNESIUM VERSUS HUMOTELINITE

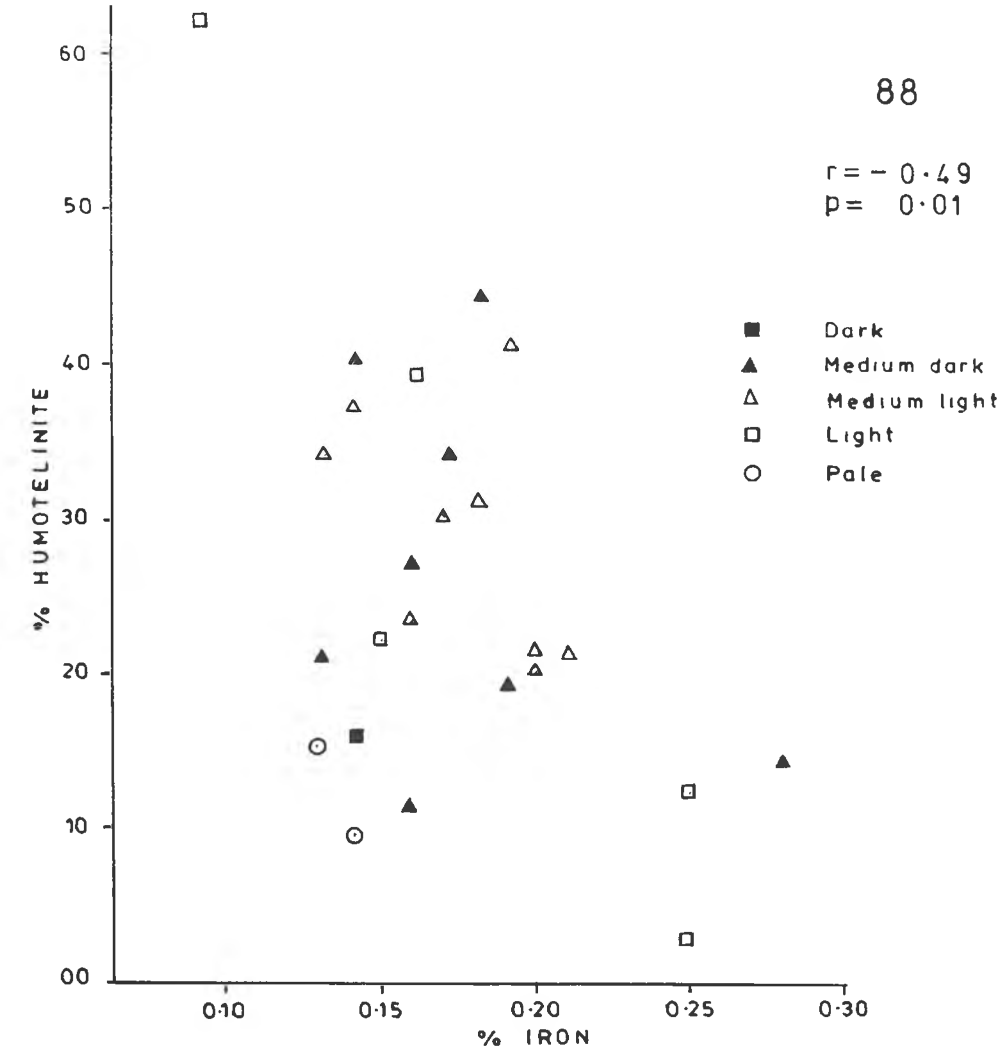


FIG 28 IRON VERSUS HUMOTELINITE

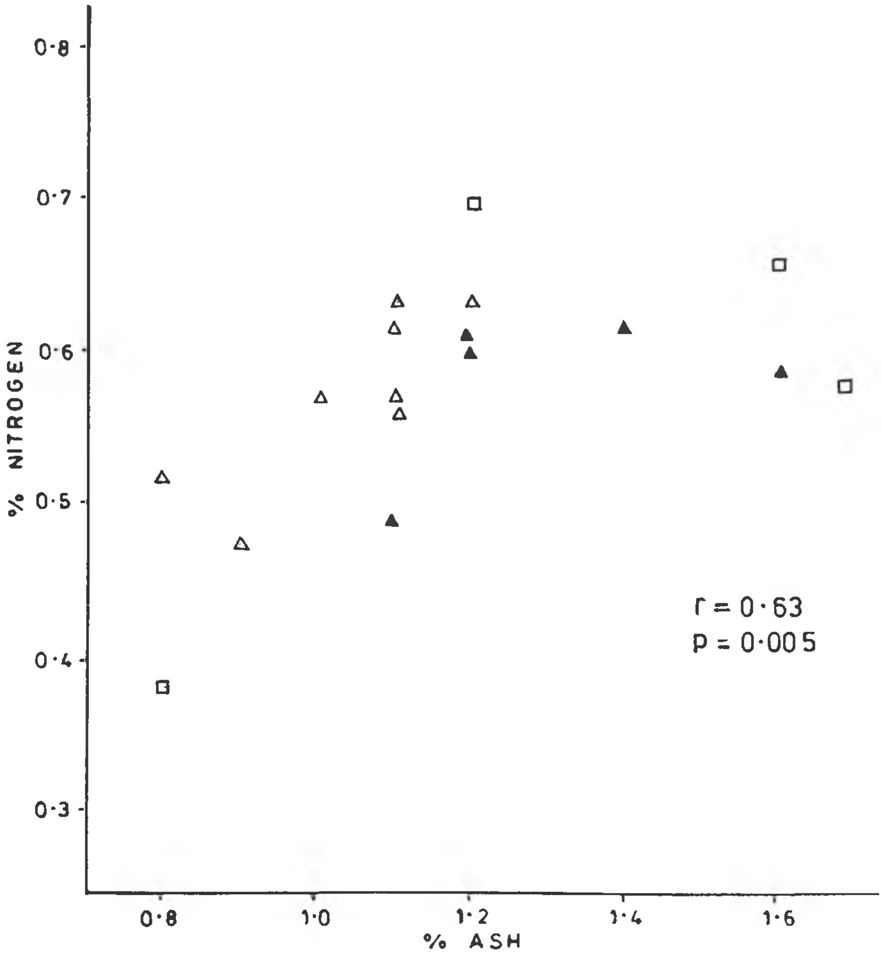


FIG 29 ASH VERSUS NITROGEN

8 SUMMARY

8.1 The moisture content of brown coal in general shows a small but significant increase towards the dark end of the lithotype spectrum.

8.2 The moisture content of pale lithotype coal is markedly lower than for other lithotypes.

8.3 The content of humotelinite is a basic determinant of moisture content and like liptinite correlates better with moisture than do either lithotype or colour index. This may also apply to certain individual macerals such as texto-ulminite.

8.4 High values of estimated free wood will increase moisture content, although the relationship between free wood and moisture content is poor where the content of free wood is below about 30%.

8.5 A strong inverse relationship exists between nitrogen content and the amount of residual woody or cellulosic material in brown coal. From this, it seems likely that nitrogen content comprises a useful indicator of the amount of woody tissue present.

8.6 Localised variations in the concentration of calcium, magnesium and iron as soluble inorganic constituents in brown coal appear to be strongly related to the amount of residual wood in the coal.

8.7 Residual woody tissue is less likely to retain the mobile inorganic constituents calcium, magnesium and iron than corresponding coal groundmass. This is probably due to the fact that woody tissue contains fewer free carboxylate groups.

8.8 Ash yield in Latrobe Valley coals is likely to show, in general terms, some degree of significant correlation with nitrogen as a consequence of the relationship of nitrogen to calcium, magnesium and iron.

9 ACKNOWLEDGEMENTS

The invaluable assistance freely given by all SEC Coal Science Laboratory personnel involved with this study is most gratefully acknowledged. Particular thanks are due to Mr D Attwood who supplied the statistical analyses, to Mr W Stacey who reviewed much of the text and to Mr T Rohde of Morwell Survey Section for drafting many of the figures. Permission granted by the Exploration and Geological Division of the SEC to use the figures in the section dealing with geology is also gratefully acknowledged, as is the assistance rendered by Mr M George and Mr P Bolger of the Petrological Section.

This project would not have been possible without the generous sponsorship of the State Electricity Commission of Victoria and I am very much indebted to this organisation for its support and for permission to present this work.

Finally, it was the late Mr Lou Kiss, former Head of Coal Science at the Herman Research Laboratory, who initiated and guided this project with characteristic enthusiasm and informed perception. It is in recognition of his outstanding contribution to the understanding of brown coal that I wish this thesis to be dedicated.

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APPENDIX 1

STANDARD ABBREVIATIONS USED FOR BROWN COAL LITHOTYPES BY SECV

STANDARD ABBREVIATION USED FOR
BROWN COAL LITHOTYPES BY SECV

ABBREVIATION	LITHOTYPE
Dk	Dark
M-d	Medium Dark
M-l	Medium Light
Lt	Light
Pa	Pale

APPENDIX 2

STATISTICAL ANALYSES AND CORRELATION MATRIX

STATISTICAL ANALYSES

A correlation matrix for all variables measured on Bore 3651 N was computer generated by Mr D Attwood, whose report is included overleaf.

The two parameters which have been used to quantify the degree of correlation between any two values are the Pearson Linear correlation coefficient
r and the significance probability p.

The correlation coefficient r is the figure listed as the correlation between any two variables in the correlation matrix. It is a measure of the apparent degree of association between the two variables and the closer the correlation coefficient approaches the value of 1, the higher is the degree of association. Where a minus sign is present, the relationship is inverse and the line of best fit on a graphical plot of the relationship would display a negative gradient. Unless otherwise specified, correlation coefficients given in this thesis were generated using the Pearson Product Moment method.

As the correlation coefficient does not take into account sample size, it is necessary to include the significance probability p in order to assess the significance of a correlation. The significance probability is determined from the student t value:

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

where -

t = student t value

N = No of samples

r = correlation coefficient

The value of p indicates the likelihood of the particular correlation being due to chance if the assumption of a linear model is valid. For instance p 0.001 indicates that there is a less than 0.1% likelihood of the correlation occurring by chance and p 0.05 indicates that this has increased to 5%. It is usually considered that a correlation is significant when $p < 0.05$.

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No CS/82/59

Date 5 May 1982

da/wc

LABORATORY REPORT

SUBJECT THE CORRELATION OF MOISTURE CONTENT AND ESTIMATED FREE WOOD WITH OTHER CHEMICAL AND PETROLOGICAL VARIABLES FOR BORE 3651N

REPORT

This report gives the correlation matrix for all variables measured on Bore 3651N. In particular, it highlights those variables with statistically significant correlations with moisture (a.r.) and estimated free wood. However, it should be noted that the two highest moisture samples #17 (70.30%) and #48 (70.10%) had the two highest free wood contents and with these two samples deleted the correlation between moisture and free wood was not significant.

SUBMITTED BY:	Bob Gaulton	~~SECT/DIV~~/DEPT	Coal Production		
PHONE:					
ACCEPTED BY:	D Attwood	SECT	Coal Science	ON	19/4/82
ACTIVITY NO:	922226				
REMARKS:	Results stored on microfiche T2240DAH				

SIGNED David Attwood
David Attwood
STATISTICIAN

LTK.

TABLE 1 : PARAMETERS SIGNIFICANTLY CORRELATED WITH MOISTURE (A.R.) AT THE 5% LEVEL ($p<0.05$)

	PARAMETER	CORRELATION	SAMPLE SIZE	SIGNIFICANCE
4	Ash	-0.4373	50	$0.001<p<0.01$
5	Iron (n.p.)	-0.3007	50	$0.01<p<0.05$
6	Calcium	-0.4316	50	$0.001<p<0.01$
7	Magnesium	-0.3399	50	$0.01<p<0.05$
9	Chlorine	-0.3458	50	$0.01<p<0.05$
10	Nitrogen	-0.5758	17	$0.01<p<0.05$
12	Sp. Energy (Gross Dry)	-0.4352	50	$0.001<p<0.01$
13	Sp. Energy (Gross Wet)	-0.9188	50	$p<0.001$
14	Sp. Energy (Net Wet)	-0.9232	50	$p<0.001$
15	Colour Index	-0.4599	50	$p<0.001$
16	Lithotype (from Colour)	0.4468	50	$0.001<p<0.01$
17	Lithotype (as logged)	0.5316	50	$p<0.001$
19	Humotelinite	0.6944	25	$p<0.001$
21	Liptinite	-0.6854	25	$p<0.001$
22	Inertinite	-0.4756	25	$0.01<p<0.05$
24	Estimated Free Wood	0.4881	50	$p<0.001$
28	Texto-ulminite	0.7133	25	$p<0.001$
36	Sporinite	-0.6443	25	$p<0.001$
40	Lipto detrinite	-0.6660	25	$p<0.001$
41	Sclerotinite	-0.5493	25	$0.001<p<0.01$

TABLE 2 : PARAMETERS SIGNIFICANTLY CORRELATED WITH ESTIMATED FREE WOOD AT THE 5% LEVEL ($p \quad 0.05$)

PARAMETER		CORRELATION	SAMPLE SIZE	SIGNIFICANCE
2	Moisture (a.r.)	0.4881	50	$p < 0.001$
3	Moisture (d.b.)	0.5148	50	$p < 0.001$
5	Iron (n.p.)	-0.4082	50	$0.001 < p < 0.01$
6	Calcium	-0.3624	50	$0.001 < p < 0.01$
7	Magnesium	-0.4501	50	$0.001 < p < 0.01$
9	Chlorine	-0.3460	50	$0.01 < p < 0.05$
10	Nitrogen	0.8768	17	$p < 0.001$
13	Specific Energy (gross wet)	-0.3455	50	$0.01 < p < 0.05$
14	Specific Energy (net wet)	-0.3491	50	$0.01 < p < 0.05$
18	Humodetrinite	-0.7759	25	$p < 0.001$
19	Humotelinite	0.8918	25	$p < 0.011$
25	Attrinite	-0.7998	25	$p < 0.001$
28	Texto-ulminite	0.9054	25	$p < 0.001$
29	Eu-ulminite	0.4460	25	$p < 0.001$

		MOIST-AR 2	MOIST-DB 3	ASH 4	IRON(NP) 5	CALCIUM 6
MOIST-AR	2	1.0000				
MOIST-DB	3	0.9897	1.0000			
ASH	4	-0.4373	-0.4512	1.0000		
IRON(NP)	5	-0.3007	-0.3160	0.4648	1.0000	
CALCIUM	6	-0.4316	-0.4496	0.4588	0.8687	1.0000
MAGNES	7	-0.3399	-0.3626	0.4090	0.9303	0.8833
SODIUM	8	0.2330	0.2013	-0.0584	0.3477	0.3134
CHLORINE	9	-0.3458	-0.3299	-0.0422	-0.0832	-0.0183
NITROGEN	10	-0.5758	-0.5749	0.6253	0.8351	0.8117
SULPHUR	11	-0.2562	-0.2619	0.6716	0.0892	0.1160
S.EN.-GD	12	-0.4352	-0.3769	0.0955	-0.1614	-0.0268
S.EN.-GW	13	-0.9188	-0.8884	0.3387	0.1232	0.2724
S.EN.-NW	14	-0.9232	-0.8934	0.3439	0.1268	0.2768
COLOUR	15	-0.4599	-0.4073	0.2376	0.1672	0.2209
LITH-COL	16	0.4468	0.4028	-0.2405	-0.0821	-0.1493
LITH-LOG	17	0.5316	0.4818	-0.3400	-0.0980	-0.2300
H-DETRIN	18	-0.2632	-0.2896	-0.0210	0.5346	0.4186
H-TELIN	19	0.6944	0.7023	-0.0813	-0.4922	-0.5203
H-COLLIN	20	0.2945	0.2431	-0.0750	-0.1564	-0.1374
LIPTIN	21	-0.6854	-0.6418	0.1851	-0.0382	0.1633
INERTIN	22	-0.4756	-0.4183	-0.0712	-0.0170	0.1095
MINERALS	23	0.0957	0.1229	-0.4116	-0.2843	-0.1987
FREEWOOD	24	0.4881	0.5148	-0.1530	-0.4082	-0.3624
ATTRIN	25	-0.2581	-0.2758	-0.0679	0.5315	0.4112
DENSIN	26	0.0390	0.0133	0.1730	-0.1052	-0.0640
TEXTIN	27	0.1387	0.1116	-0.0225	0.1564	0.0892
T-ULMIN	28	0.7133	0.7326	-0.1302	-0.4991	-0.5245
E-ULMIN	29	0.2638	0.2437	0.1290	-0.3400	-0.3306
T-GELIN	30	0.1786	0.1501	0.2056	-0.1583	-0.1107
D-GELIN	31	0.1101	0.0774	0.1016	-0.0744	0.0152
E-GELIN	32	0.0147	-0.0096	0.2790	0.0212	0.1681
P-GELIN	33	0.1347	0.1097	-0.1087	-0.1908	-0.2126
PHLOBAPH	34	0.2261	0.1935	-0.1183	0.1117	0.0762
P-PHLOB	35	0.1968	0.1751	-0.3823	-0.1401	-0.1931
SPORIN	36	-0.6443	-0.5836	0.1928	-0.0448	0.1275
CUTINITE	37	0.2571	0.2392	-0.2612	-0.0919	-0.2437
RESINITE	38	-0.0418	-0.0774	0.1677	0.1563	0.0656
SUBERIN	39	-0.0767	-0.0742	-0.0555	0.0181	0.1005
L-DETRIN	40	-0.6660	-0.6244	0.1871	-0.0435	0.1509
SCLEROT	41	-0.5493	-0.4830	-0.0386	-0.0306	0.1422

TABLE 3

CORRELATION MATRIX

MAGNES 7	SODIUM 8	CHLORINE 9	NITROGEN 10	SULPHUR 11	S. EN. -GD 12
1.0000					
0.4104	1.0000				
-0.0686	-0.3157	1.0000			
0.8527	0.0267	0.2611	1.0000		
-0.0089	-0.2284	0.1404	0.2642	1.0000	
-0.2236	-0.5152	0.4464	-0.3308	0.3242	1.0000
0.1291	-0.4138	0.4877	0.4771	0.3143	0.7268
0.1337	-0.4094	0.4892	0.4819	0.3139	0.7200
0.1508	-0.2521	0.0185	0.0277	0.0039	0.6051
-0.0744	0.3341	-0.0139	-0.0812	-0.0148	-0.6033
-0.0901	0.2524	-0.1512	-0.1990	-0.3121	-0.7154
0.5599	0.1080	0.1176	0.7800	-0.1808	-0.2404
-0.5530	0.1093	-0.5198	-0.8295	0.1026	-0.2308
-0.1307	0.4549	-0.2351	-0.1728	-0.0561	-0.5417
-0.0002	-0.4573	0.6253	-0.0002	0.1466	0.8618
0.0110	-0.4360	0.5741	0.1021	0.0473	0.5142
-0.2308	-0.2486	0.0564	-0.4488	-0.2495	0.1008
-0.4501	-0.0687	-0.3460	-0.8768	0.0016	0.0453
0.5467	0.0822	0.0807	0.6486	-0.3137	-0.2097
-0.0742	0.0692	0.1070	0.1172	0.5161	-0.0578
0.0095	0.3360	-0.3216	0.0362	0.0714	-0.2157
-0.5448	0.0072	-0.4814	-0.7963	0.0221	-0.1761
-0.3498	0.2319	-0.2612	-0.4237	0.2918	-0.2049
-0.2215	0.1129	0.0521	0.0698	0.4066	-0.1272
-0.0044	0.1618	-0.1154	0.0897	0.2186	-0.2579
0.1057	-0.0071	0.2350	0.3287	0.2397	-0.2171
-0.1926	0.0840	-0.1090	-0.3334	-0.1921	-0.2505
0.0826	0.4050	-0.3570	-0.1563	-0.2463	-0.4752
-0.0354	0.6533	-0.1452	-0.0315	-0.3870	-0.4007
-0.0578	-0.4878	0.6859	0.0855	0.2153	0.7930
-0.1595	-0.0405	-0.1178	0.0433	-0.1293	-0.1272
0.1057	0.0224	-0.4023	0.3551	0.1791	-0.3204
0.1039	0.0292	-0.0977	-0.3173	-0.2493	-0.1397
-0.0096	-0.4467	0.6357	0.0596	0.1684	0.8874
0.0100	-0.4197	0.5527	-0.0162	-0.0198	0.5922

TABLE 3 (CONT'D)
CORRELATION MATRIX

		S.EN -GW 13	S.EN -NW 14	COLOUR 15	LITH-COL 16	LITH-LOG 17	H-DETRIN 18	H-TELIN 19	H-COLLIN 20	LIPTIN 21	INERTIN 22	MINERALS 23
S.EN -GW	13	1.0000										
S.EN -NW	14	0.9998	1.0000									
COLOUR	15	0.5767	0.5732	1.0000								
LITH-COL	16	-0.5533	-0.5512	-0.9313	1.0000							
LITH-LOG	17	-0.6575	-0.6548	-0.8308	0.8259	1.0000						
H-DETRIN	18	0.0853	0.0912	-0.1707	0.1171	0.3227	1.0000					
H-TELIN	19	-0.5946	-0.5991	-0.1732	0.2117	0.1519	-0.8130	1.0000				
H-COLLIN	20	-0.4379	-0.4353	-0.5331	0.5165	0.4251	-0.2707	0.3715	1.0000			
LIPTIN	21	0.8563	0.8529	0.6781	-0.6481	-0.8458	-0.2501	-0.3301	-0.4569	1.0000		
INERTIN	22	0.5616	0.5607	0.3712	-0.3478	-0.3030	0.1335	-0.3252	-0.4272	0.3623	1.0000	
MINERALS	23	-0.0274	-0.0291	0.0672	-0.0432	0.1739	-0.0449	0.1458	-0.2701	-0.0796	0.3791	1.0000
FREEWOOD	24	-0.3455	-0.3491	0.0830	-0.0957	-0.0492	-0.7759	0.8918	0.1288	-0.1530	-0.1798	0.2669
ATTRIN	25	0.0956	0.1009	0.0019	-0.0665	0.2108	0.9606	-0.8059	-0.2870	-0.1942	0.1184	-0.0291
DENSIN	26	-0.0555	-0.0544	-0.5818	0.6326	0.3312	-0.0756	0.1511	0.1171	-0.1460	0.0254	-0.0470
TEXTIN	27	-0.1885	-0.1882	-0.0697	0.0880	0.0402	-0.0525	0.1081	0.3231	-0.1851	-0.1440	0.0605
T-ULMIN	28	-0.5849	-0.5901	-0.0845	0.0996	0.1216	-0.7610	0.9648	0.2385	-0.3148	-0.2658	0.2163
E-ULMIN	29	-0.2767	-0.2768	-0.3612	0.4521	0.1680	-0.6140	0.6361	0.4928	-0.1456	-0.3113	-0.1843
T-GELIN	30	-0.1820	-0.1824	-0.5361	0.4352	0.1466	-0.2707	0.2572	0.5226	-0.1308	-0.2366	-0.3230
D-GELIN	31	-0.1884	-0.1867	-0.4333	0.3748	0.1787	-0.1731	0.2198	0.4607	-0.2022	-0.2525	-0.2900
E-GELIN	32	-0.1046	-0.1013	-0.2537	0.1806	0.1037	-0.0005	0.0114	0.1603	-0.0755	0.0077	0.1624
P-GELIN	33	-0.2015	-0.2001	-0.2357	0.3287	0.3155	-0.2952	0.2936	0.6806	-0.2059	-0.2581	-0.0200
PHLOBAPH	34	-0.3616	-0.3595	-0.1069	0.1315	0.2702	-0.0841	0.2082	0.5962	-0.3682	-0.3031	-0.1154
P-PHLOB	35	-0.3042	-0.3022	-0.1672	0.1292	0.2485	0.1660	-0.0070	0.4884	-0.4085	-0.1131	-0.0590
SPORIN	36	0.8042	0.8008	0.6206	-0.5584	-0.7482	-0.2608	-0.2497	-0.3592	0.8478	0.6452	0.0160
CUTINITE	37	-0.2327	-0.2337	-0.2564	0.2824	0.2045	0.0854	-0.0527	0.1943	-0.1040	-0.2810	-0.2856
RESINITE	38	-0.1144	-0.1094	-0.2415	0.1806	0.2784	0.4374	-0.1869	-0.2173	-0.3192	0.1247	-0.1561
SUBERIN	39	-0.0002	0.0020	0.1618	-0.1197	-0.1361	-0.1283	0.0124	0.0439	0.1723	-0.1931	-0.1172
L-DETRIN	40	0.8520	0.8481	0.6590	-0.6387	-0.8325	-0.2416	-0.3265	-0.4612	0.9841	0.3467	-0.0601
SCLEROT	41	0.6498	0.6483	0.5531	-0.5189	-0.5224	-0.0350	-0.2657	-0.3291	0.5022	0.9243	0.2659

TABLE 4
CORRELATION MATRIX

		FREEWOOD 24	ATTRIN 25	DENSIN 26	TEXTIN 27	T-ULMIN 28	E-ULMIN 29	T-GELIN 30	D-GELIN 31	E-GELIN 32	P-GELIN 33	PHLOBAPH 34
FREEWOOD	24	1.0000										
ATTRIN	25	-0.7008	1.0000									
DENSIN	26	-0.1006	-0.3499	1.0000								
TEXTIN	27	0.0392	0.0148	-0.2301	1.0000							
T-ULMIN	28	0.9054	-0.7309	0.0572	-0.0244	1.0000						
E-ULMIN	29	0.4460	-0.7220	0.5203	-0.0089	0.4482	1.0000					
T-GELIN	30	0.0762	-0.3732	0.4263	0.0435	0.1937	0.3379	1.0000				
D-GELIN	31	0.0432	-0.3127	0.5382	0.0727	0.1041	0.4764	0.5372	1.0000			
E-GELIN	32	-0.0797	-0.0651	0.2319	-0.1952	0.0478	-0.0146	0.4403	0.0528	1.0000		
P-GELIN	33	0.1792	-0.2659	-0.0410	0.0060	0.2026	0.4709	0.0966	-0.0560	0.0142	1.0000	
PHLOBAPH	34	0.1510	0.0332	-0.4025	0.4880	0.1449	0.0801	-0.2048	-0.1436	-0.1444	0.5174	1.0000
P-PHLOB	35	-0.1702	0.2216	-0.2353	0.4086	-0.0346	-0.1219	0.0649	-0.0249	-0.0043	0.1139	0.4448
SPORIN	36	-0.1392	-0.2379	-0.0253	-0.1106	-0.2489	-0.0851	-0.0878	-0.1247	-0.0234	-0.1912	-0.3257
CUTINITE	37	-0.2250	0.0745	0.0208	0.1993	-0.1202	0.0937	0.2022	0.1833	-0.1204	0.0876	0.0148
RESINITE	38	-0.2259	0.3644	0.1669	-0.0030	-0.2109	-0.0252	-0.0964	0.0071	-0.1757	-0.2607	-0.1032
SUBERIN	39	0.1275	-0.0361	-0.2956	0.1143	-0.0468	0.1469	-0.3231	0.0873	-0.1687	0.1038	0.2254
L-DETRIN	40	-0.1575	-0.1937	-0.1195	-0.2125	-0.2978	-0.1741	-0.0833	-0.2254	-0.0448	-0.2098	-0.3965
SCLEROT	41	-0.0904	0.0106	-0.1562	-0.0129	-0.2260	-0.2791	-0.2196	-0.1824	-0.1351	-0.2025	-0.2028

		P-PHLOB 35	SPORIN 36	CUTINITE 37	RESINITE 38	SUBERIN 39	L-DETRIN 40	SCLEROT 41
P-PHLOB	35	1.0000						
SPORIN	36	-0.2930	1.0000					
CUTINITE	37	0.0892	-0.1426	1.0000				
RESINITE	38	-0.0640	-0.2747	0.1452	1.0000			
SUBERIN	39	-0.0336	0.1502	0.1913	-0.0865	1.0000		
L-DETRIN	40	-0.4082	0.7973	-0.1528	-0.3465	0.0141	1.0000	
SCLEROT	41	-0.0697	0.7550	-0.2824	-0.0344	-0.0632	0.4733	1.0000

TABLE 5 : SAMPLE SIZE FOR EACH OF THE PARAMETERS (LISTED BY NUMBER)

PARAMETER NUMBER(S)	SAMPLE SIZE
2 to 9, 11 to 17, 24	50
10	17
18 to 23, 25 to 41	25

TABLE 6 : SIGNIFICANT ABSOLUTE VALUES OF THE CORRELATION COEFFICIENT

SAMPLE	SIGNIFICANCE PROBABILITY		
SIZE	p=0.05	p=0.01	p=0.001
17	0.4821	0.6055	0.7246
25	0.3961	0.5052	0.6177
50	0.2787	0.3610	0.4515

DETERMINATION OF COLOUR INDEX

DETERMINATION OF COLOUR INDEX

Colour Index, a quantitative indicator of lithotype used to supplement field lithotype logging, was determined using a 'Hunterlab' colour meter. The procedure used in the determinations is outlined below, but it should be noted that this technique has since been further refined and re-standardised - see footnote*.

Technique used -

- Approximately 250 grams of bed moist coal representing each sample was crushed to pass a 3/16" (3.76 mm) screen and laid out for air drying at room temperature in a paper tray for four days.

- Of the air-dried sample, around 200 grams were selected and hand ground using a mortar and pestle until all of this coal passed through a 52 mesh (300 micron) sieve.

- The 'Hunterlab' colour meter was standardised and measurements were carried out on each sample without further delay. Each sample was turned through 90° and re-read to ensure consistency of the results.

- The colour index value for each sample was calculated using the following relationship:

$$CI = (\bar{L} + \bar{a} + \bar{b}) \times 10.0 + 100$$

Where CI is the colour index and $\bar{L}$, $\bar{a}$ and $\bar{b}$ are the standardised values of the L, a and b from the colour meter. L, a and b correspond to 'white-black', 'yellow-blue' and 'red-green'.

In using Colour Index as an indicator of lithotype, the following criteria applied:

COLOUR INDEX	APPARENT LITHOTYE
38 to 66	Dark
67 to 93	Medium Dark
94 to 121	Medium Light
122 to 148	Light
149 to 176	Pale

* A detailed description of the sample preparation, colour measurement and computation of Colour Index is set out in an internal SECV Research and Development Department Report entitled 'Measurement of the Colour of Dry, Soft Brown Coal' [Attwood et al, November 1983].

APPENDIX 4

ESTIMATION OF PERCENTAGE FREE WOOD

ESTIMATION OF PERCENTAGE FREE WOOD

The term 'free wood' refers to that part of the coal sample consisting of macroscopic woody material liberated from the coal groundmass during light crushing of air-dried, minus 3/16" (3.76 mm) lump sized coal.

No proven, time efficient method of separating free wood from groundmass was available and the following procedure was devised in order to generate a quantitative estimate of the amount of free wood present in each sample.

Method used to estimate Percentage Free Wood:

- Approximately 20 grams of minus 3/16" (3.76 mm) air-dried coal was selected from each sample and seived to remove the minus 1 mm fraction of coal.

- The coal remaining on the 1 mm and larger screens was placed on a white background under a strong light source. The free wood component of the coal was then separated by hand under a magnifier with the aid of a dental pick and fine tweezers.

- The separate 'wood' and 'groundmass' fractions thus obtained were then placed in individual 25 ml measuring cylinders and the volume occupied by each fraction noted. Where the woody fraction consisted largely of long fragments, the contents of the measuring cylinders were gently broken up with a glass rod in order to approximate the solids to voids ratio of the corresponding groundmass fraction.

. The estimated percentage free wood was then determined directly from the measured volumetric proportion of wood material and groundmass.

It was decided at the time to make a simple volumetric comparison rather than weighing the respective wood and groundmass fractions as it was considered that different woods and/or their differing degrees of gelification might affect specific gravity, thereby diminishing the validity of a comparison of the components by weight. Any such influence has since been shown to be negligible [George 1981 - Personal Communication] and it is now suggested that weighing of wood and groundmass fractions can and does provide a more accurate and reliable method of estimating the percentage of free wood. The use of volumetric comparison as described is still, however, likely to be valid as an estimate. Cross checks employing weighing of the respective fractions on an accurate electronic balance were performed during the initial determinations on three separate samples. In each case the results indicated that the estimated free wood content obtained through weighing varied by less than 5 per cent of the estimate obtained via volumetric comparison.

LITHOTYPE LOG : BORE 3651 N

LITHOTYPE LOG - BORE 3651N

Dk = DARK LITHOTYPE

M-d = MEDIUM DARK LITHOTYPE

M-l = MEDIUM LIGHT LITHOTYPE

Lt = LIGHT LITHOTYPE

Pa = PALE LITHOTYPE

X = XYLITE number on a scale of 0 to 10 where X0 indicates no wood visible and X10 indicates high concentration of wood.

G = GELIFICATION number on a scale of 0 to 10 where G0 indicates no evidence of gelification and G10 indicates coal is highly gelified.

DEPTH FROM	TO	LITHOTYPE	X	G	COMMENTS
3.8 -	4.6	Dk	1	6	Some Fusinitic layers
4.6 -	5.1	M-d	2	4	Scattering of light coloured fragments of bark and other cuticle
5.1 -	5.3	M-d	1	4	
5.3 -	6.0	M-d	2	4	Some contamination with silt at around 6.0 metres depth
6.0 -	6.5	M-d	1	5	
6.5 -	7.2	M-d	1	4	
7.2 -	7.7	M-l	3	1	

DEPTH FROM	TO	LITHOTYPE	X	G	COMMENTS
7.7 -	8.6	M-1	2	1	
8.6 -	9.0	M-1	6	1	Some large pieces of wood
9.0 -	10.8	M-1	2	1	Some light coloured cuticle at around 9.6-9.7 m depth Core reduced to 50 mm diam.
10.8 -	11.2	M-1	9	0	Mainly Wood
11.2 -	12.5	M-1	1	1	
12.5 -	12.8	M-1	2	1	
12.8 -	13.0	M-1	10	1	Massive Wood
13.0 -	13.9	M-1	2	1	Abundant Bark, some stems
13.9 -	14.0	Lt/M-1	1	0	
14.0 -	14.15	Pa	0	0	
14.15 -	14.3	Lt/M-1	0	0	
14.3 -	14.5	M-1	0	0	
14.5 -	15.9	M-1	2	1	Disseminated bark - light colour, some layers of cuticle
15.9 -	16.1	M-1	9	3	Mostly wood
16.1 -	17.2	M-1	3	1	Woody inclusions at around 16.8 m
17.2 -	17.7	M-d	5	3	

DEPTH FROM TO	LITHOTYPE	X	G	COMMENTS
17.7 - 17.9	M-1	2	1	
17.9 - 18.3	M-1	3	2	
18.3 - 18.5	Lt	6	1	
18.5 - 18.7	Lt/M-1	6	2	
18.7 - 19.15	Pa	2	0	
19.15 - 19.2	M-1	10	0	Massive Wood
19.2 - 19.5	Pa	1	0	
19.5 - 19.75	M-1/Lt	3	3	
19.75 - 19.9	M-1	2	2	
19.9 - 20.2	M-d/M-1	3	3	
20.2 - 20.4	M-1/Lt	2	1	Disseminated cuticle
20.4 - 20.6	M-d/M-1	6	3	Convoluted woody inclusions
20.6 - 20.7	Lt	2	2	
20.7 - 21.1	M-1	2	1	
21.1 - 21.25	M-1	10	1	Massive wood
21.25 - 21.4				Core Missing
21.4 - 21.6	Lt/M-1	3	2	One 4 mm long fragment of resin
21.6 - 22.0	M-1	2	2	

BASE DATA

6.1 Coal Analysis - Traditional (Dry) Basis

6.2 Coal Petrology - Maceral Groups, Lithotype and Estimated Free Wood

6.3 Coal Petrology - Maceral Analysis

6.1 -COAL ANALYSIS : TRADITIONAL (DRY) BASIS

SAMPLE		MOISTURE		ASH %db	INORGANICS %db					ULTIMATE %db		SPECIFIC ENERGY - MJ/kg		
NO	DEPTH (M) FROM TO	%ar	%db		Fe (NP)	Ca	Mg	Na	Cl	N	S (tot)	GROSS DRY	GROSS WET	NET WET
1	3.80 - 4.13	65.9	193.26	0.8	0.14	0.07	0.12	0.05	0.11	-	0.23	26.36	8.99	7.14
2	4.13 - 4.47	65.8	192.40	1.0	0.16	0.06	0.13	0.05	0.09	-	0.24	26.45	9.05	7.19
3	4.47 - 4.80	67.5	207.69	1.4	0.20	0.07	0.14	0.05	0.11	-	0.25	25.90	8.42	6.54
4	4.80 - 5.13	68.4	216.46	0.9	0.16	0.06	0.12	0.05	0.08	-	0.25	26.49	8.37	6.49
5	5.13 - 5.36	67.3	205.81	1.0	0.19	0.06	0.15	0.05	0.10	-	0.24	26.30	8.60	6.73
6	5.36 - 5.69	66.2	195.86	0.8	0.16	0.06	0.13	0.05	0.08	-	0.24	26.06	8.81	6.95
7	5.69 - 6.02	66.3	196.74	0.8	0.14	0.06	0.11	0.05	0.08	-	0.24	26.24	8.84	6.98
8	6.02 - 6.35	65.8	192.40	1.0	0.16	0.07	0.13	0.05	0.08	-	0.24	25.97	8.88	7.03
9	6.35 - 6.80	66.3	196.74	0.9	0.15	0.06	0.12	0.05	0.08	-	0.25	25.96	8.75	6.89
10	6.80 - 7.13	65.6	190.79	0.9	0.13	0.06	0.10	0.05	0.07	-	0.24	26.33	9.06	7.21
11	7.13 - 7.46	65.7	191.55	0.8	0.14	0.06	0.11	0.04	0.08	-	0.24	26.33	9.03	7.18
12	7.46 - 7.80	66.5	198.51	0.7	0.16	0.07	0.13	0.05	0.09	-	0.21	25.94	8.69	6.83
13	7.80 - 8.13	65.8	192.40	1.0	0.19	0.08	0.14	0.06	0.07	-	0.22	26.14	8.94	7.09
14	8.13 - 8.50	65.1	186.53	1.1	0.22	0.13	0.16	0.05	0.09	-	0.23	27.06	9.44	7.60
15	8.50 - 9.80	66.1	194.99	1.2	0.23	0.09	0.17	0.05	0.07	-	0.29	26.43	8.96	7.10

ar - as received; db - dry basis; So - suplhur (organic); NP - Non Pyritic inorganics

6.1 -COAL ANALYSIS : TRADITIONAL (DRY) BASIS

SAMPLE		MOISTURE		ASH %db	INORGANICS %db					ULTIMATE %db		SPECIFIC ENERGY - MJ/kg		
NO	DEPTH (M) FROM TO	%ar	%db		Fe (NP)	Ca	Mg	Na	Cl	N	S (tot)	GROSS DRY	GROSS WET	NET WET
16	9.80-10.80	65.8	192.40	1.1	0.20	0.08	0.15	0.05	0.03	0.63	0.21	26.05	8.91	7.06
17	10.80-11.13	70.3	236.70	1.1	0.19	0.07	0.13	0.05	0.05	0.56	0.19	26.19	7.78	5.87
18	11.13-11.46	64.1	178.55	1.2	0.25	0.10	0.18	0.05	0.07	0.70	0.22	25.65	9.21	7.38
19	11.46-11.80	64.0	177.78	1.3	0.28	0.11	0.20	0.06	0.07	-	0.19	25.98	9.35	7.52
20	11.80-12.13	65.0	185.71	1.1	0.24	0.09	0.18	0.05	0.09	-	0.20	26.29	9.20	7.36
21	12.13-12.46	63.6	174.73	1.5	0.27	0.12	0.19	0.05	0.07	-	0.26	26.32	9.58	7.75
22	12.46-12.80	63.8	176.24	1.2	0.21	0.08	0.15	0.05	0.07	0.63	0.26	25.93	9.39	7.56
23	12.80-13.13	66.0	194.12	0.8	0.14	0.07	0.12	0.05	0.05	0.52	0.20	26.20	8.91	7.05
24	13.13-13.46	65.3	188.18	1.1	0.24	0.10	0.18	0.05	0.03	-	0.27	26.29	9.12	7.20
25	13.46-13.80	65.4	189.02	1.3	0.20	0.09	0.16	0.05	0.06	-	0.26	26.49	9.17	7.32
26	13.80-14.13	61.6	160.42	1.5	0.25	0.11	0.19	0.05	0.11	-	0.30	27.72	10.64	8.85
27	14.13-14.46	63.6	174.73	1.6	0.29	0.13	0.22	0.06	0.07	-	0.36	26.04	9.48	7.66
28	14.46-14.60	64.4	180.90	1.5	0.23	0.11	0.18	0.06	0.07	-	0.30	25.76	9.17	7.34
29	14.60-14.93	65.6	190.70	1.2	0.20	0.09	0.15	0.05	0.09	-	0.26	25.86	8.90	7.05
30	14.93-15.30	65.8	192.40	1.1	0.17	0.07	0.14	0.05	0.08	-	0.23	25.89	8.85	7.00

ar - as received; db - dry basis; So - suplhur (organic); NP - Non Pyritic; as - as sampled; M&I - Minerals and inorganics

6.1 - COAL ANALYSIS : TRADITIONAL (DRY) BASIS

SAMPLE		MOISTURE		ASH %db	INORGANICS %db					ULTIMATE %db		SPECIFIC ENERGY - MJ/kg		
NO	DEPTH (M) FROM TO	%ar	%db		Fe (NP)	Ca	Mg	Na	Cl	N	S (tot)	GROSS DRY	GROSS WET	NET WET
31	15.30-15.63	66.6	199.40	1.0	0.16	0.07	0.13	0.05	0.08	-	0.23	25.79	8.61	6.75
32	15.63-15.96	67.4	206.75	1.0	0.17	0.07	0.13	0.08	0.06	0.57	0.23	25.98	8.47	6.60
33	15.96-16.30	64.8	184.09	0.9	0.13	0.06	0.11	0.05	0.05	0.47	0.19	26.07	9.18	7.34
34	16.30-16.63	64.5	181.69	1.2	0.20	0.08	0.15	0.06	0.06	0.61	0.24	26.24	9.32	7.48
35	16.63-16.96	65.2	187.36	1.2	0.19	0.09	0.14	0.05	0.06	0.60	0.25	26.59	9.25	7.41
36	16.96-17.30	66.7	200.30	1.1	0.18	0.08	0.13	0.05	0.05	0.57	0.26	26.39	8.79	6.92
37	17.30-17.60	66.6	199.40	1.1	0.14	0.06	0.11	0.05	0.07	0.49	0.22	26.15	8.73	6.87
38	17.60-17.93	64.3	180.11	1.6	0.17	0.07	0.12	0.05	0.06	0.59	0.48	27.01	9.64	7.81
39	17.93-18.26	66.5	198.51	1.4	0.18	0.08	0.14	0.05	0.07	0.62	0.37	26.27	8.80	6.94
40	18.26-18.60	64.9	184.90	1.7	0.16	0.08	0.12	0.05	0.09	0.58	0.42	26.74	9.39	7.55
41	18.60-18.90	64.3	180.11	1.4	0.15	0.07	0.12	0.04	0.13	-	0.46	27.87	9.95	8.12
42	18.90-19.20	63.3	172.48	1.0	0.13	0.06	0.11	0.04	0.10	-	0.24	29.36	10.78	8.96
43	19.20-19.50	60.0	150.00	1.0	0.14	0.07	0.11	0.03	0.15	-	0.24	29.60	11.84	10.06
44	19.50-19.90	63.6	174.73	1.6	0.17	0.08	0.13	0.04	0.08	-	0.41	27.33	9.95	8.13
45	19.90-20.25	65.4	181.69	1.2	0.17	0.08	0.14	0.04	0.10	-	0.25	26.15	9.28	7.45

ar - as received; db - dry basis; So - suplhur (organic); NP - Non Pyritic; as - as sampled; M&I - Minerals and inorganics

6.1 - COAL ANALYSIS : TRADITIONAL (DRY) BASIS

SAMPLE		MOISTURE		ASH %db	INORGANICS %db					ULTIMATE %db		SPECIFIC ENERGY - MJ/kg		
NO	DEPTH (M) FROM TO	%ar	%db		Fe (NP)	Ca	Mg	Na	Cl	N	S (tot)	GROSS DRY	GROSS WET	NET WET
46	20.25-20.60	64.8	184.09	1.4	0.15	0.07	0.13	0.04	0.07	-	0.38	26.97	9.49	7.65
47	20.60-20.90	64.9	184.90	1.5	0.28	0.09	0.14	0.04	0.08	0.67	0.42	27.29	9.58	7.74
48	20.90-21.25	70.1	234.45	0.8	0.09	0.04	0.08	0.04	0.05	0.38	0.27	27.34	8.17	6.27
49	21.40-21.65	65.7	191.55	1.6	0.15	0.06	0.12	0.04	0.05	0.66	0.29	25.81	8.85	7.00
50	21.65-22.00	63.2	171.74	1.7	0.15	0.06	0.12	0.04	0.05	-	0.26	26.19	9.64	7.82

ar - as received; db - dry basis; So - suplhur (organic); NP - Non Pyritic; as - as sampled; M&I - Minerals and inorganics

6.2

COAL PETROLOGY : MACERAL GROUPS, LITHOTYPE AND ESTIMATED FREE WOOD

Sample		Colour Index	Macro Lithotype		Percentage Volume						
Sample Number	Block Number		By Colour Index	By Logging	Humo-detrinite	Humo-telinite	Humo-collinite	Liptinite	Inertinite	Minerals	Estimated Free Wood
1	1057	63	5	5	76.0	15.8	4.6	2.6	0.6	0.4	1
2	-	65	5	5	-	-	-	-	-	-	4
3	-	77	4	4.5	-	-	-	-	-	-	5
4	1058	80	4	4	59.2	27.2	8.8	4.2	0.6	0	4
5	-	83	4	4	-	-	-	-	-	-	2
6	1043	67	4	4	80.2	11.0	5.8	2.4	0.6	0	1
7	-	68	4	4	-	-	-	-	-	-	9
8	-	76	4	4	-	-	-	-	-	-	20
9	-	72	4	4	-	-	-	-	-	-	4
10	1041	65	4	4	64.6	21.2	10.0	4.0	0.2	0	5
11	-	92	3.5	3.5	-	-	-	-	-	-	10
12	-	105	3	3	-	-	-	-	-	-	12
13	-	102	3	3	-	-	-	-	-	-	5
14	-	103	3	3	-	-	-	-	-	-	2
15	-	91	3	3	-	-	-	-	-	-	18
16	1059	118	3	3	69.6	20.2	4.8	5.0	0.2	0.2	5

6.2

COAL PETROLOGY : MACERAL GROUPS, LITHOTYPE AND ESTIMATED FREE WOOD

Sample		Colour Index	Macro Lithotype		Percentage Volume						
Sample Number	Block Number		By Colour Index	By Logging	Humo-detrinite	Humo-telinite	Humo-collinite	Liptinite	Inertinite	Minerals	Estimated Free Wood
17	1047	119	3	3	49.4	41.4	3.4	5.8	0	0	35
18	1060	121	2	3	74.0	12.4	5.2	7.2	1.0	0.2	2
19	-	122	2.5	3	-	-	-	-	-	-	6
20	-	111	3	3	-	-	-	-	-	-	2
21	-	111	3	3	-	-	-	-	-	-	1
22	1076	113	3	3	66.2	21.0	9.0	3.2	0.6	0	7
23	1051	109	3	3	44.6	37.2	7.4	10.8	-	-	25
24	-	119	3	3	-	-	-	-	-	-	3
25	-	111	3	3	-	-	-	-	-	-	7
26	1044	129	2	2	69.4	2.6	2.2	25.2	0.6	0	2
27	-	122	3	3	-	-	-	-	-	-	1
28	-	92	4	3	-	-	-	-	-	-	2
29	-	90	3.5	3	-	-	-	-	-	-	1
30	-	104	3	3	-	-	-	-	-	-	2
31	1040	107	3	3	55.8	23.4	10.4	10.2	0.2	0	6
32	1061	111	3	3	57.6	29.6	9.4	3.2	0.2	0	10

6.2

COAL PETROLOGY : MACERAL GROUPS, LITHOTYPE AND ESTIMATED FREE WOOD

Sample		Colour Index	Macro Lithotype		Percentage Volume						
Sample Number	Block Number		By Colour Index	By Logging	Humo-detrinite	Humo-telinite	Humo-collinite	Liptinite	Inertinite	Minerals	Estimated Free Wood
33	1046	108	3	3	45.4	34.2	7.0	13.0	0.2	0.2	30
34	1052	122	2.5	3	64.0	21.4	8.4	6.2	0	0	10
35	1062	122	2.5	3	66.6	19.4	4.6	8.4	1.0	0	18
36	1042	99	3	3.5	49.0	31.6	9.4	9.4	0.4	0.2	21
37	1053	92	4	4	40.6	39.6	14.6	5.2	0	0	23
38	1054	90	4	3	47.0	34.2	4.0	14.0	0.8	0	14
39	1056	82	4	3	39.2	43.6	10.6	6.4	0.2	0	21
40	1045	101	3	2	34.0	38.6	10.0	17.2	0.2	0	30
41	-	121	2.5	1.5	-	-	-	-	-	-	7
42	1063	162	1	1	45.4	15.6	1.6	37.2	0.2	0	5
43	1048	175	1	1	52.2	9.4	2.6	33.4	2.2	0.2	2
44	-	107	2.5	2.5	-	-	-	-	-	-	8
45	-	102	3	4	-	-	-	-	-	-	13
46	-	95	3	3	-	-	-	-	-	-	3
47	1049	114	3	3	71.6	14.0	4.2	10.0	0.2	0	5
48	1050	130	2	3	29.6	61,8	4.0	3.4	0.8	0.4	60

6.2

COAL PETROLOGY : MACERAL GROUPS, LITHOTYPE AND ESTIMATED FREE WOOD

Sample		Colour Index	Macro Lithotype		Percentage Volume						
Sample Number	Block Number		By Colour Index	By Logging	Humo-detrinite	Humo-telinite	Humo-collinite	Liptinite	Inertinite	Minerals	Estimated Free Wood
49	1055	123	2	3	68.2	21.8	4.0	5.8	0.2	0	2
50	-	122	2	3	-	-	-	-	-	-	10

6.3 COAL PETROLOGY : MACERAL ANALYSIS

SAMPLE NUMBER	Percentage Volume																		
	Attrinite	Densinite	Textinite	Texto-Ulminite	Eu-Ulminite	Telo-Gelinite	Detro-Gelinite	Eu-Gelinite	Pori-Telinite	Phlob-aphinite	Pseudo-phlob.	Sporinite	Cutinite	Resinite	Suber-inite	Lipto-detrinite	Sclerot-inite	Semi-fusinite	Fusinite	Inerto-detrinite
1	66.4	9.6	0.8	12.8	2.2	0.2	0.4	0.4	1.4	1.2	1.0	0	0	0.2	0.4	2.0	0	0.2	0.2	0.2
4	53.2	6.0	1.4	23.6	2.2	2.2	0.2	0.2	2.6	1.4	2.2	0.8	0.4	0.4	0.6	2.0	0.2	0.4	0	0
6	75.0	5.2	1.8	6.6	2.6	1.2	1.2	0	0.6	1.4	1.4	0	0.2	0.6	0.4	1.2	0.2	0.2	0.2	0
10	60.4	4.2	3.0	13.6	4.6	3.2	3.4	0	0.8	1.0	1.6	0.2	0.4	0.8	0.2	2.4	0.2	0	0	0
16	68.8	0.8	5.4	13.4	1.4	0.2	0.2	0	1.6	1.5	1.2	0	0.4	0.6	0.8	3.2	0.2	0	0	0
17	49.4	0	1.2	34.6	5.6	0.4	0.6	0	0.6	1.6	0.2	0.6	0.2	0.2	2.4	2.4	0	0	0	0
18	73.0	1.0	1.4	9.8	1.2	0.2	0.4	0.4	1.0	2.2	1.0	1.0	0	0.6	0.6	5.0	0.6	0	0.2	0.2
22	66.0	0.2	3.4	15.0	2.6	0.2	0.4	0	2.4	3.8	2.2	0	0	0.6	0.4	2.2	0.6	0	0	0
23	42.8	1.8	2.0	32.0	3:2	0.2	0.8	0	1.2	4.0	1.2	0.8	0.2	0.4	2.8	6.6	0	0	0	0
26	68.0	1.4	1.0	1.6	0	0	0.6	0	0.2	1.2	0.2	2.0	0	0.2	2.8	20.2	0.6	0	0	0
31	55.8	0	5.2	13.0	5.2	0.6	2.8	0.2	1.4	3.4	2.0	1.2	0.6	0.2	4.8	3.4	0.2	0	0	0
32	56.8	0.8	6.2	19.0	4.4	0.6	0.4	0	0.8	3.8	3.8	0.4	0	0.2	0.6	2.0	0.2	0	0	0
33	45.2	0.2	3.4	23.0	7.8	0.2	0.8	0	3.0	1.8	1.2	1.0	0	0.4	5.0	6.6	0.2	0	0	0
34	62.0	2.0	1.4	15.6	4.4	0.4	2.0	0	1.6	2.2	2.2	0.6	0	0.2	2.0	3.4	0	0	0	0

6.3-COAL PETROLOGY : MACERAL ANALYSIS

SAMPLE NUMBER	Percentage Volume																		
	Attrinite	Densinite	Textinite	Texto-Ulminite	Eu-Ulminite	Telo-Gelinite	Detro-Gelinite	Eu-Gelinite	Pori-Telinite	Phlob-aphinite	Pseudo-phlob.	Sporinite	Cutinite	Resinite	Suber-inite	Lipto-detrinite	Sclerot-inite	Semi-fusinite	Fusinite	Inerto-detrinite
35	66.0	0.6	2.0	15.6	1.8	0.2	1.2	0	0.6	2.0	0.6	0.6	0	1.0	1.6	5.2	0.8	0	0.2	0
36	48.8	0.2	6.8	22.6	2.2	0.8	1.0	0	2.0	4.4	1.2	1.0	0	0.2	1.2	7.0	0.4	0	0	0
37	38.0	2.6	1.4	26.6	11.6	0.8	0.8	0	7.6	4.6	0.8	0.4	0.2	0	1.4	3.2	0	0	0	0
38	32.8	14.2	2.6	19.0	12.6	0.8	1.6	0	0.6	1.0	0	2.0	0.2	1.2	1.2	9.4	0.4	0	0.4	0
39	24.6	14.6	2.4	31.6	9.6	2.8	5.4	0.2	1.2	0.6	0.4	1.0	0	0	0.6	4.8	0.2	0	0	0
40	31.4	2.6	2.8	29.6	6.2	3.8	0.8	0.6	2.0	1.8	1.0	1.6	0	0	0.6	15.0	0.2	0	0	0
42	44.4	1.0	0.8	12.0	2.8	0.4	0.2	0	0.6	0.2	0.2	2.2	0.2	0	0.4	34.4	0.2	0	0	0
43	51.6	0.6	2.2	6.8	0.4	0	0	0	0.8	0.8	1.0	5.4	0	0	1.4	26.6	2.2	0	0	0
47	70.8	0.8	4.8	8.8	0.4	0.6	0.2	0	0.8	2.4	0.2	1.0	0.2	0.4	1.2	7.2	0	0	0	0.2
48	29.2	0.4	2.4	54.8	4.6	0.2	0.4	0	0.8	1.6	1.0	0.4	0	0.2	0.2	2.6	0.6	0	0	0.2
49	67.4	0.8	0.8	20.2	0.8	0.2	0.4	0.2	0.6	1.6	1.0	0.6	0	0.8	1.2	3.2	0	0	0	0.2

LOCATION OF BORE 3651 NARRACAN

BORE 3651 NARRACAN

LOCATION

1 Australian Map Grid Co-ordinates

441 076.9 M EAST - 557 058.2 M NORTH

2 SECV Latrobe Valley Grid Co-ordinates

394 555.5 M EAST - 264 495.4 M NORTH

RELATIVE LEVEL OF BORE COLLAR

+ 41.6 M A.H.D

GENERAL DESCRIPTION OF LOCATION

Within Yallourn Open Cut below dredger erection site at Hernes Oak on No 2 Level, Western Batters. West side of Y304/Y308 conveyor interchange.

APPENDIX 8

A GUIDE TO THE MAPPING OF BROWN COAL LITHOTYPES
IN EXPOSED COAL FACES : SAMPLE LITHOTYPE MAP INCLUDED

A GUIDE TO THE FIELD MAPPING OF BROWN COAL LITHOTYPES IN EXPOSED FACES

GENERAL

A short account of the basic considerations in recording lithotype banding in exposed coal faces is here included as a guide for those who may be required to carry out such work. It also gives some explanation as to how the appended diagram, which shows overall lithotype trends in the operating faces at Yallourn Open Cut, was arrived at.

The visual identification and recording of lithotype banding in open cuts follows the same fundamental procedure as for normal geological mapping. The various discrete elements present are first cursorily identified from a suitable distance, followed where required by closer examination, including hand specimens and, if necessary, supplementary analytical procedures. The final interpretation is then recorded in the form of a diagram and written observations. Depending on specific requirements, the diagrams produced can range from accurately surveyed, detailed presentations on a small scale to large scale freehand sketches which show the major apparent trends but do not attempt to record all observable banding. The appended diagram falls into the latter category.

In a sense, lithotype mapping in brown coal open cuts is a relatively straightforward procedure as in most cases the banding can be represented in terms of a simple layer cake model (Prints 1-5, Section 4). The main difficulties arise from the fact that the banding is rarely distinct enough to be easily recognised, particularly along the operating faces where the coal is seldom left for long enough to effect sufficient drying of the outer surface.

The prominent banding shown in Prints 1-10 (Section 4) is somewhat atypical in degree of clarity, as the areas or faces shown have been selected for photography as a result of displaying particularly good exposures of lithotypes. This means that in general these faces have, at the time of being photographed, dried and weathered to the point where the maximum degree of contrast of colour, shrinkage cracking and textural variations between lithotypes has developed. In the majority of cases, lithotype banding in coal faces is likely to be much less apparent than is depicted in these prints.

Before commencing to map brown coal lithotypes, it is desirable that a reasonably accurate profile of the face or faces to be mapped is obtained and plotted at a scale suited to the amount of detail required. Locations or distance along the face should be tied to a convenient point of reference, such as frame numbers on the face conveyors or measured distance from some fixed, locatable point.

Where the face is both high and steep, as is usually the case, it is difficult to obtain accurate measurements of the height and thickness of individual lithotype bands. This can be overcome by using standard survey sighting procedures or by simply dangling a tape or knotted line over the face at regular intervals. Such measures are, however, time consuming and are unnecessary, except for detailed investigations or mapping on a small scale. It is usually sufficient, for practical mining purposes, to estimate the height and thickness of lithotype banding visible in a face of known height and to produce a carefully checked freehand sketch of this banding.

It must be emphasised that the visual mapping of lithotypes is by nature a subjective process which relies heavily on comparisons with the appearance of surrounding coal lithotypes. This means that it is quite possible that an apparently dark lithotype mapped in Morwell Open Cut may, for instance, rank as only a medium dark lithotype in the Yallourn Seam. The employment of colour index determinations can in this regard be very useful as supportive information.

CONDITION OF THE FACE

For effective mapping to be carried out, the face should ideally have been permitted to stand exposed to the weather for sufficient time to allow the outer 20 mm or so of coal to air dry thoroughly. This normally takes about 2 months in the summer season of Victoria, but can be much longer in winter, particularly if the face is oriented away from the sun.

It is when the outer surface of the coal is properly dry that the lithotype banding present approaches maximum visible contrast due to development of the various characteristics previously mentioned (see Sections 4.1, 4.3). If the face is left to stand indefinitely, for instance as part of a permanent batter system, this contrast usually remains fairly high for a further 18 months to 2 years, after which time the face begins to degenerate in certain ways which begin to obscure the lithotypes. The main factors which develop in response to advanced weathering of the coal face are as follows:

- Continued propogation and widening of shrinkage cracking to the point where the face becomes a loose mosaic of dried coal which begins to slough off.

- The appearance of a greyish discolouration on the weathered coal surface. This effect can be clearly seen in Print A (at the end of this appendix), where the segment of coal face affected is of an orientation which caused it to receive more direct sunlight and thereby ultimately more weathering, than the rest of the coal face.

- The gradual accumulation of weathered coal detritus which builds up along the toe of the face and within face irregularities and bucketwheel digging terraces caused by excavation.

- The growth of algae and foliage on faces which remain moist at the surface due to drainage and seepage or which rarely receive any direct sunlight (see Print B).

At the other end of the scale, freshly excavated bed moist coal faces generally show, as mentioned in Section 4, little or no obvious evidence of the presence of lithotype banding, although distinct pale or light lithotypes can sometimes be seen. Faces which are wet from rainfall or spraying are also totally unsuited to mapping as the coal colours are darkened by surface moisture and the reflective sheen tends to obscure detail.

WEATHER AND LIGHTING CONDITIONS

In general, lithotype banding is best seen, assuming the condition of the face to be suitable, when the incident rays of the sun are approximately normal to the coal face. This not only highlights the various subtle colour differences but eliminates oblique shadow zones created by face irregularities As the faces more often than not happen to be angled to varying degrees in relation to the passage of the sun, it is usually possible to minimise the confusing effect of face shadows by carrying out mapping on days which are lightly overcast in order to achieve conditions where the sunlight is relatively soft and diffuse. Such conditions often prevail on misty summer mornings in the Latrobe Valley.

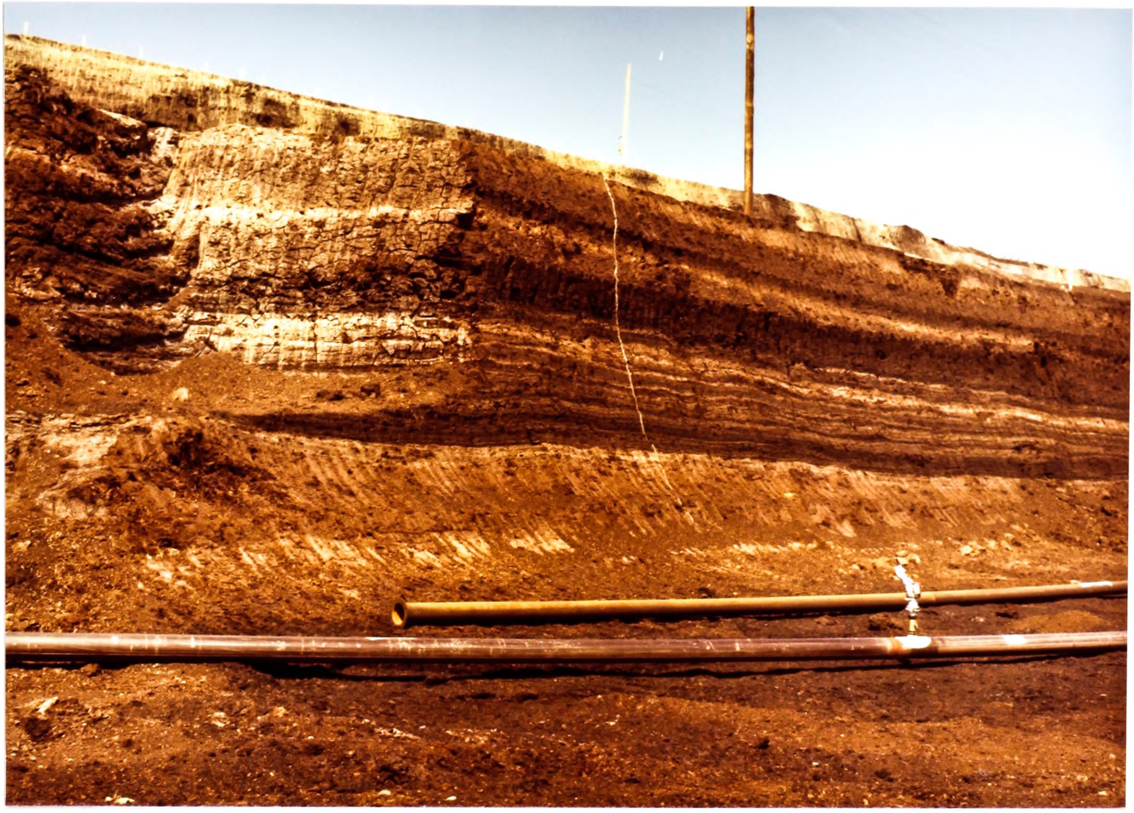
It is also important to try and limit mapping to the same approximate time of day if the exercise is a lengthy one. Lighting conditions can change quite substantially from morning to afternoon and this can have a considerable effect on interpretation.

OVERCOMING THE MAIN PROBLEMS

If the lithotype banding present in a coal face is partly obscured or otherwise unclear, it is often possible to salvage the situation to some degree. Palaeobotanical affiliations, such as the strongly developed tendency for large woody remains to be concentrated within thick medium light lithotypes at Yallourn (Prints 1, 4, 5, 6, Section 4) can provide useful indications of lithotype. Close examination of slightly air dried faces also often reveals the presence of minute shrinkage cracks, the intensity of which may give an indication as to degree of gelification and thereby the likely lithotype. Examination of hand specimens, even in the bed moist state, furnishes further information indicative of lithotype. With regard to small scale textural variations, for instance, the groundmass of dark lithotypes tends to show a layering effect in hand specimen while the groundmass of lighter lithotypes seems less structured. Stratigraphic extrapolations can also be made between separate areas which do show identifiable banding but are separated by a zone of featureless face and marker horizons such as distinct pale lithotypes can be invaluable for this purposes.

Forced and natural drying, petrographic analysis and laboratory determinations can of course be used to support, review or confirm visual mapping, although such procedures are labour intensive and time consuming. It is desirable, however, to employ some form of verification to ensure that the field observations are reasonably accurate, and a few strategically located cored bores or a program of additional face sampling will assist in providing this extra control. Other simple expedients such as examining the relative colour of a dry powder 'streak' of coal sample, as produced on emery paper, can also provide supplementary information in the field.

From the above, it could be concluded that the visual mapping of brown coal lithotypes in the field is subject to so many uncertainties and variables that its validity is open to question. The application of such mapping does not and should not, however, be considered as capable of producing data to be used in isolation. Rather it is intended to furnish rapidly generated information regarding general trends and the broad occurrence of lithotype banding for purposes of meeting practical mining requirements. If performed responsibility by an experienced or properly instructed person, the information obtained by the visual mapping of brown coal lithotypes in open cut faces can in most cases provide useful data needed to meet field objectives of selective or partially selective mining.



PRINT A

Layered lithotype banding showing partial obscuration through excessive exposure to sun's rays on transverse section of face.

No 3 Level, Southern Batters, Yallourn Open Cut

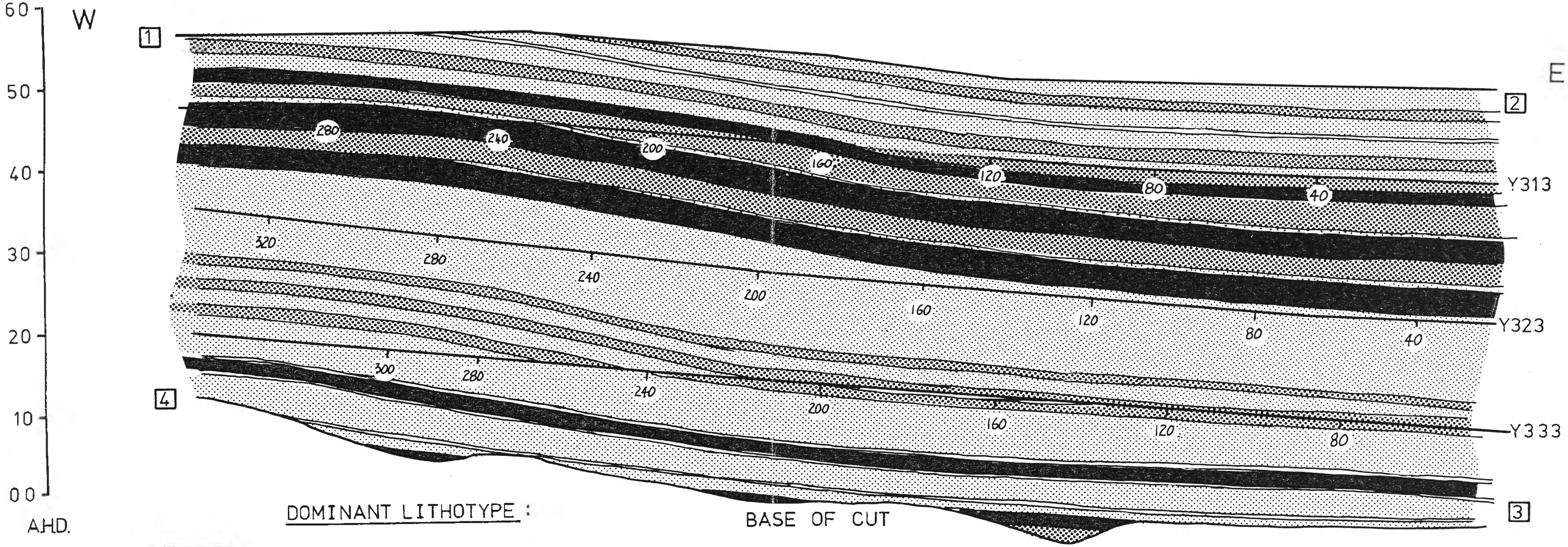
PRINT B

Lithotype banding in coal face obscured by water film, algae growth and vegetation.

No 2 Level, 'Bulge' Area, Yallourn Open Cut

LITHOTYPE BANDING OVERALL TRENDS

YALLOURN OPEN CUT EARLY TO MID 1984



DOMINANT LITHOTYPE :

DARK

MEDIUM DARK

MEDIUM LIGHT

LIGHT / PALE

SCALE :

HORIZONTAL 1 : 5000

VERTICAL 1 : 500

APPROX. LOCATIONS :

1 394900E : 266700N

2 396400E : 265200N

3 395900E : 264500N

4 394800E : 264900N

R. Goulton
6/84

PREPARATION OF BROWN COAL GRAIN MOUNTS FOR MICROSCOPIC EXAMINATION AND ANALYSIS

PREPARATION OF BROWN COAL GRAIN MOUNTS FOR MICROSCOPIC EXAMINATION AND ANALYSIS

1 CRUSHING AND GRAIN SIZING OF COAL

1.1 Sample is crushed to pass a 3.76 mm mesh grating and mixed thoroughly prior to being laid out for air drying.

1.2 100 gram (approximate) aliquot of air dried sample is further crushed (usually with a hand-held roller such as a round glass bottle), so as to pass a No 8 (2.0 mm) sieve and be retained on a No 72 (0.21 mm) sieve. Intermediate sieves are used to facilitate sieving. The resultant distribution of grain sizes should approximate the following:

1.00-2.00 mm Ø	-	20%
0.60-1.00 mm Ø	-	60%
0.20-0.60 mm Ø	-	20%

The small amount of 'fines' which pass through the No 72 (0.21 mm) screen are discarded, as they are both too small for satisfactory maceral identification under the microscope and tend to inhibit setting of resins used to manufacture the grain mounts.

2 MANUFACTURE OF GRAIN MOUNT BLOCKS

2.1 Approximately 13 g of resin* is mixed with a roughly equal amount (by volume comparison) of coal grains as prepared above and left to stand until all air bubbles cease to rise. The appropriate hardener or catalyst is then added and the mixture stirred thoroughly. The resulting suspension is poured without further delay into an aluminium mould (manufactured using heavy gauge foil and adhesive tape) approximately 30 mm x 25 mm x 17 mm and allowed to set.

2.2 Curing may be accelerated in a warm oven after the block has gelled and cooled after the initial exothermic reaction between the resin and the hardener or catalyst.

* MEDIA USED IN GRAIN MOUNTS

The grain mount blocks can be manufactured using either Polyester Resins such as 'Astic', 'Polylite' and 'Biopot' or by using epoxy resin such as 'Epimount'.

'Polylite' is the resin most commonly used by the Petrological Section of the SECV but it has the disadvantage of reacting with some of the lighter lithotype coals, causing failure of the casting to properly set and cure.

'Epimount' has a very high depth of penetration into the coal grains, often causing visible 'penetration rings'. It also exhibits some reaction with liptinite and displays strong fluorescence under blue light excitation. Epimount is used mainly where polyester resin has failed to set properly in light or pale lithotype grain mounts.

3 GRINDING AND POLISHING

3.1 After removal from the mould, which is cut away, the (vertical) face of the grain mount blocks is ground flat using a sequence of progressively finer silicon carbide papers (220, 320, 400, 600) mounted on a hand grinding machine.

3.2 Large air holes or cracks visible in the ground face may be refilled with the appropriate resin and the grinding process repeated.

3.3 Final polishing is achieved using polishing alumina spread on a rotating lap surfaced with Metron 'B' polishing cloth or equivalent. This should take less than a minute. Demineralised water is used as the wetting agent.

The procedures outlined above are detailed in a Laboratory Procedure Manual devised by the Petrological Section of the SEC. The Petrological Laboratories are located adjacent to the SEC's Herman Research Laboratory Complex at Richmond, Victoria.

PHOTOMICROGRAPHS OF POLISHED GRAIN MOUNTS OF COAL SAMPLES FROM BORE 3651 N

(PHOTOMICROGRAPHS 1 TO 34 INCLUSIVE)

INDEX AND MACERAL REFERENCE TO PHOTOMICROGRAPHS

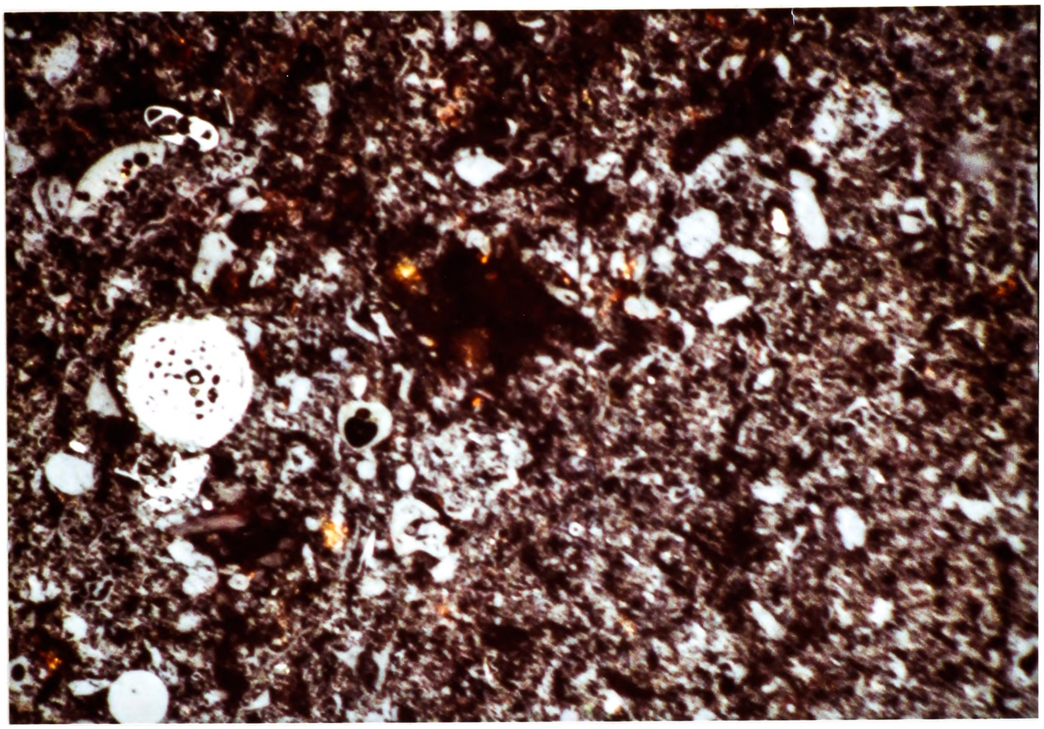
PHOTO-MICROGRAPH	PREDOMINANT MACERAL	OTHER MACERALS FEATURED	SAMPLE NO	LITHOTYPE
PM1	Attrinite	Sclerotinite	49	Lt
PM2	Attrinite	Sclerotinite	22	M-l
PM3	Attrinite	Sclerotinite	39	M-d
PM4	Attrinite	Sclerotinite	32	M-l
PM5	Attrinite	Porigelinite	33	M-l
PM6	Attrinite	-	47	M-l
PM7	Densinite	-	39	M-d
PM8	Densinite	Sclerotinite	1	Dk
PM9	Densinite	-	47	M-l
PM10	Densinite	Eugelinite	1	Dk
PM11	Densinite	Texto-Ulminite	1	Dk
PM12	Texto-Ulminite	Eu-Ulminite, Telogelinite	39	M-d
PM13	Telogelinite	Eu-Ulminite	38	M-d
PM14	Eu-Ulminite	-	38	M-d
PM15	Texto-Ulminite	-	6	M-d
PM16	Texto-Ulminite	Eu-Ulminite, Phlobaphinite	33	M-l
PM17	Texto-Ulminite	Eu-Ulminite	32	M-l
PM18	Eu-Ulminite	Phlobaphinite	1	Dk

PHOTO-MICROGRAPH	PREDOMINANT MACERAL	OTHER MACERALS FEATURED	SAMPLE NO	LITHOTYPE
PM19	Texto-Ulminite	-	39	M-d
PM20	Texto-Ulminite	-	40	M-l
PM21	Texto-Ulminite	-	49	Lt
PM22	Textinite	-	33	M-l
PM23	Textinite	-	34	Lt
PM24	Texto-Ulminite	Phlobaphinite	31	M-l
PM25	Texto-Ulminite	Phlobaphinite	17	M-l
PM26	Texto-Ulminite	-	4	M-l
PM27	Texto-Ulminite	Phlobaphinite	48	Lt
PM28	Textinite	Pseudo-Phlobaphinite	36	M-l
PM29	Fusinite	Semi-Fusinite	1	Dk
PM30	Liptodetrinite	Sporinite, Suberinite	42	Pa
PM31	Suberinite	Liptodetrinite	33	M-l
PM32	Suberinite	-	32	M-l
PM33	Liptodetrinite	Resinite	43	Pa
PM34	Resinite	-	49	Lt

Magnifications.

Where the magnification is shown as 200x the field width is 0.56mm.

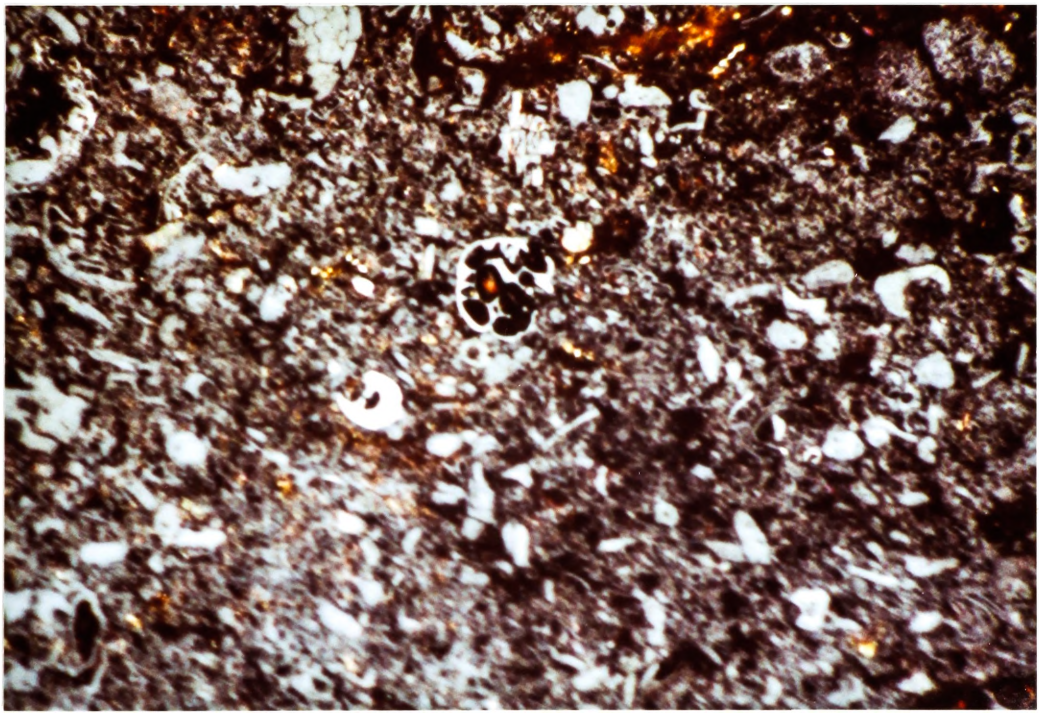
Where the magnification is shown as 320X the field width is 0.34mm.



PM 1

Attrinite with Sclerotinite (Fungal Spore) Inclusion

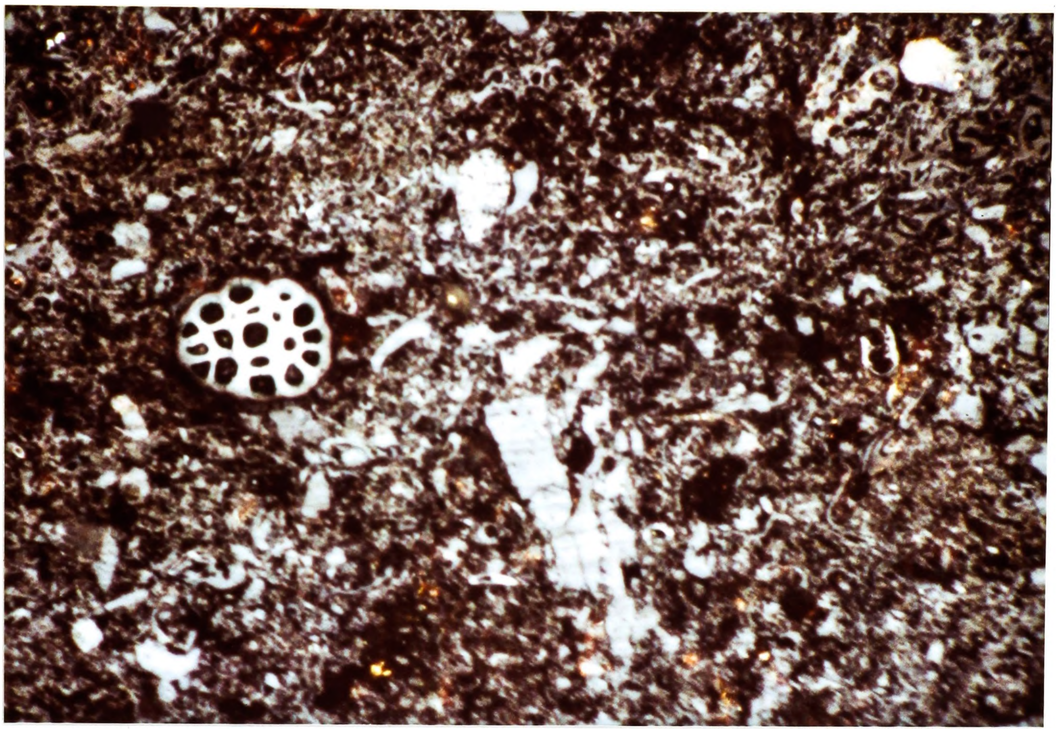
Lithotype - Light Sample No 49
(X200)



PM 2

Attrinite Containing Sclerotinite Inclusions

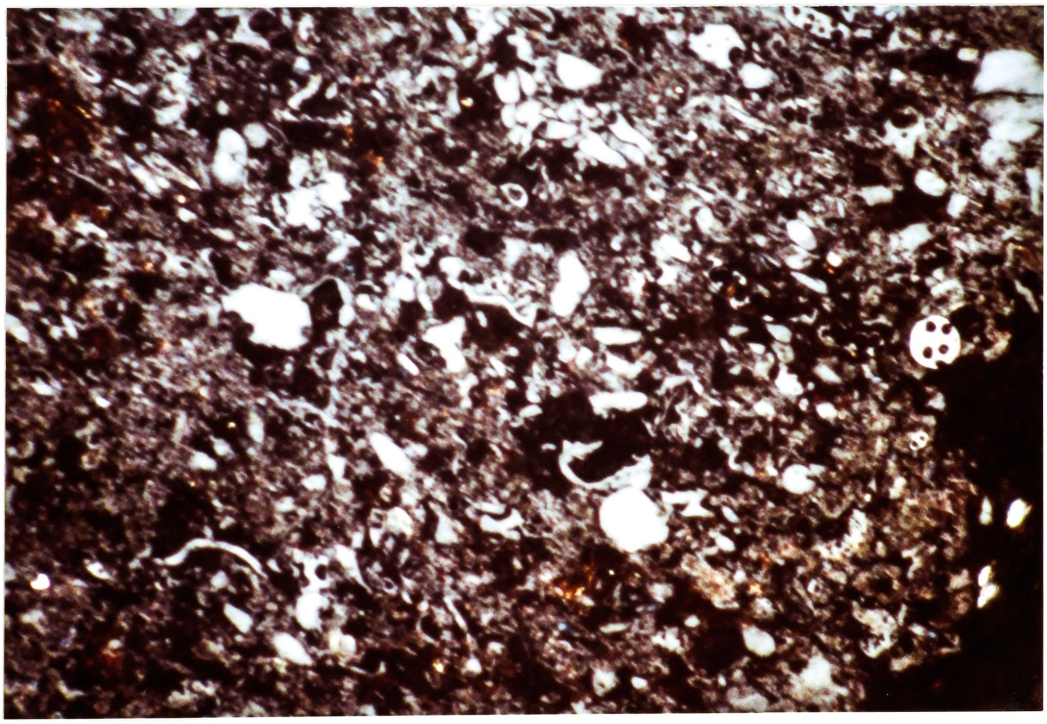
Lithotype - Medium Light Sample No 33
(X200)



PM 3

Attrinite with Sclerotinite and Fragment of Eu-Ulminite

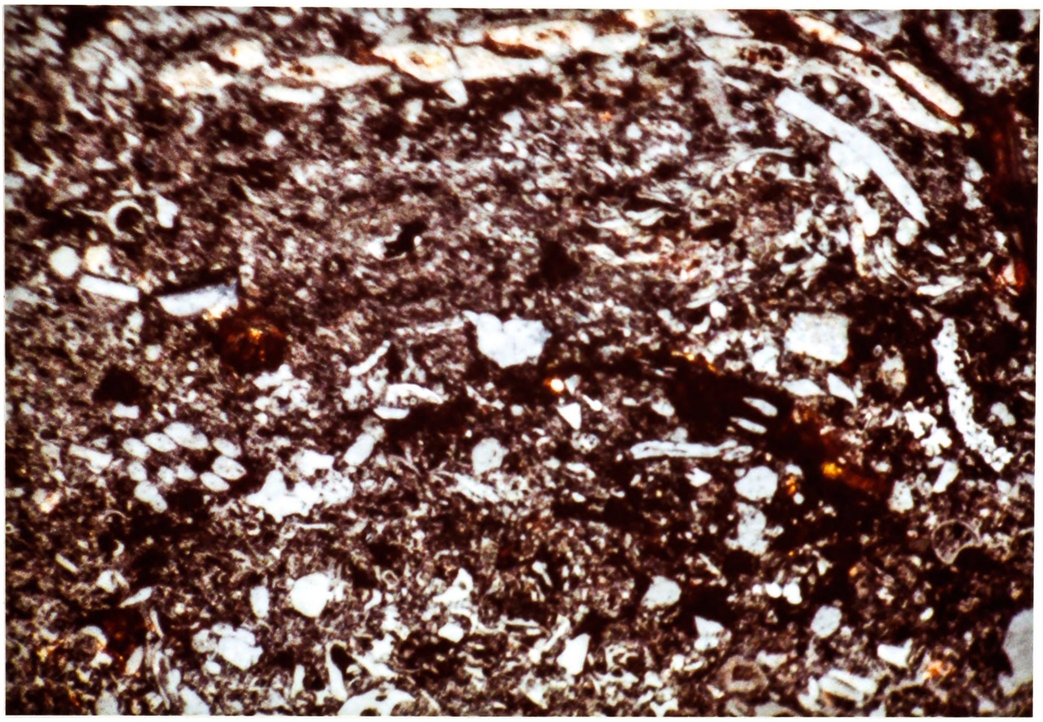
Lithotype - Medium Dark Sample No 39
(X200)



PM 4

Attrinite Containing Sclerotinite

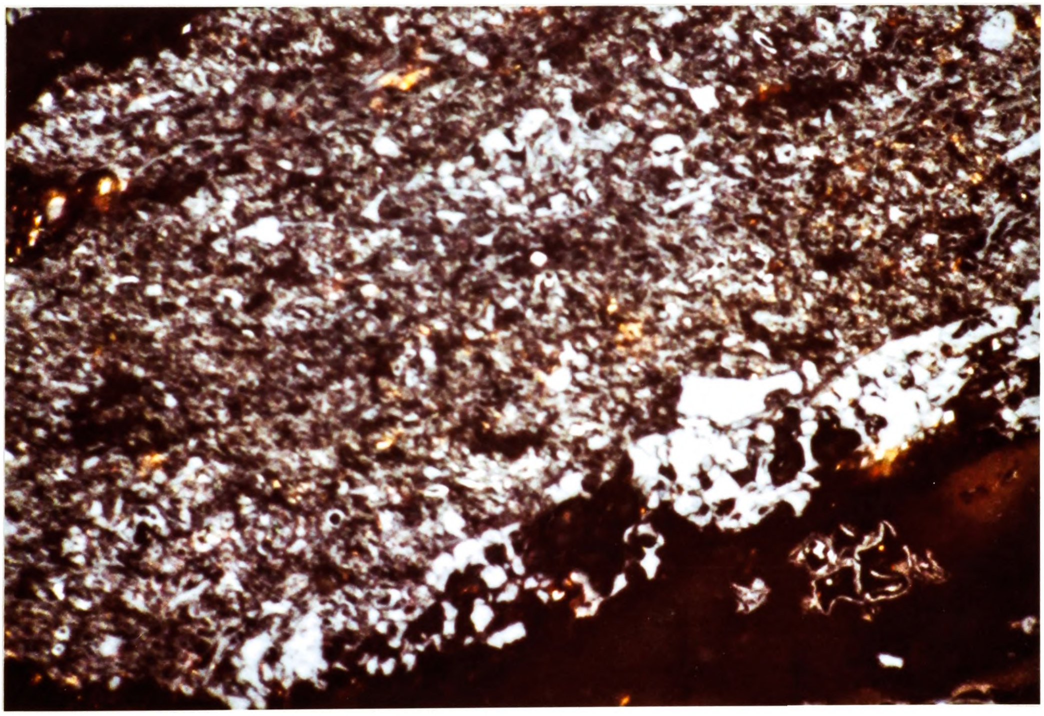
Lithotype - Medium Light Sample No 32
(X200)



PM 5

Attrinite - Some Porigelinite Present (Extreme Upper Field of View)

Lithotype - Medium Light (X200) Sample No 33



PM 6

Attrinite

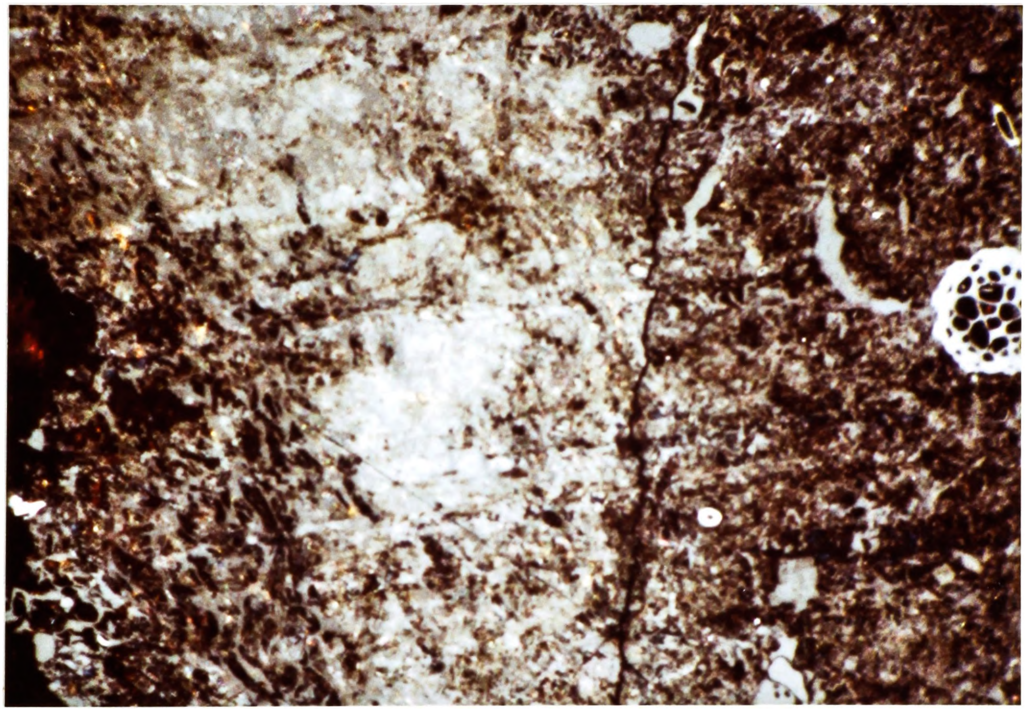
Lithotype - Medium Light (X200) Sample No 47

PM 7

Densinite

Lithotype - Medium Dark Sample No 39

(X200)

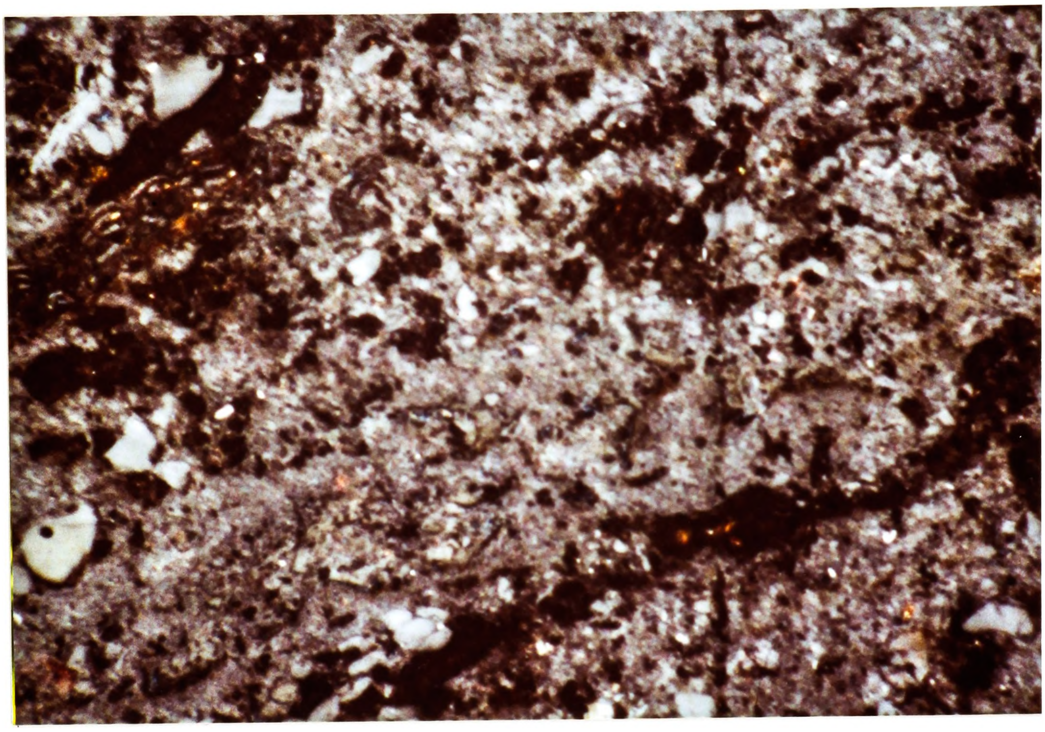


PM 8

Gelified (Densinitic) Groundmass, Featuring Sclerotinite

Lithotype - Dark Sample No 1

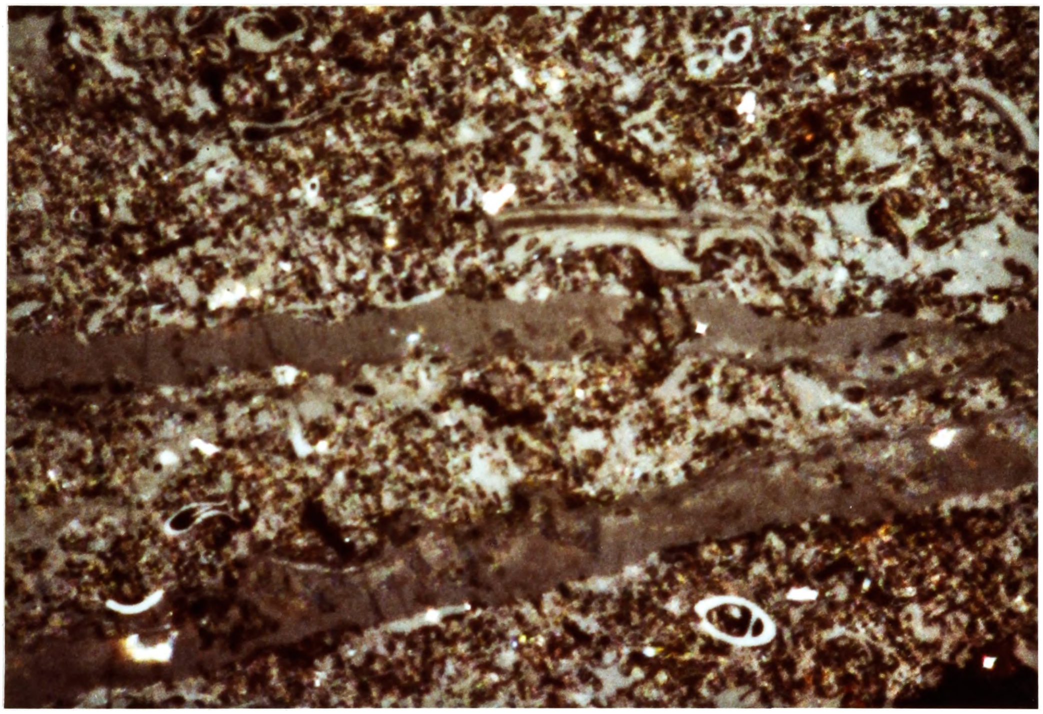
(X200)



PM 9

Densinite

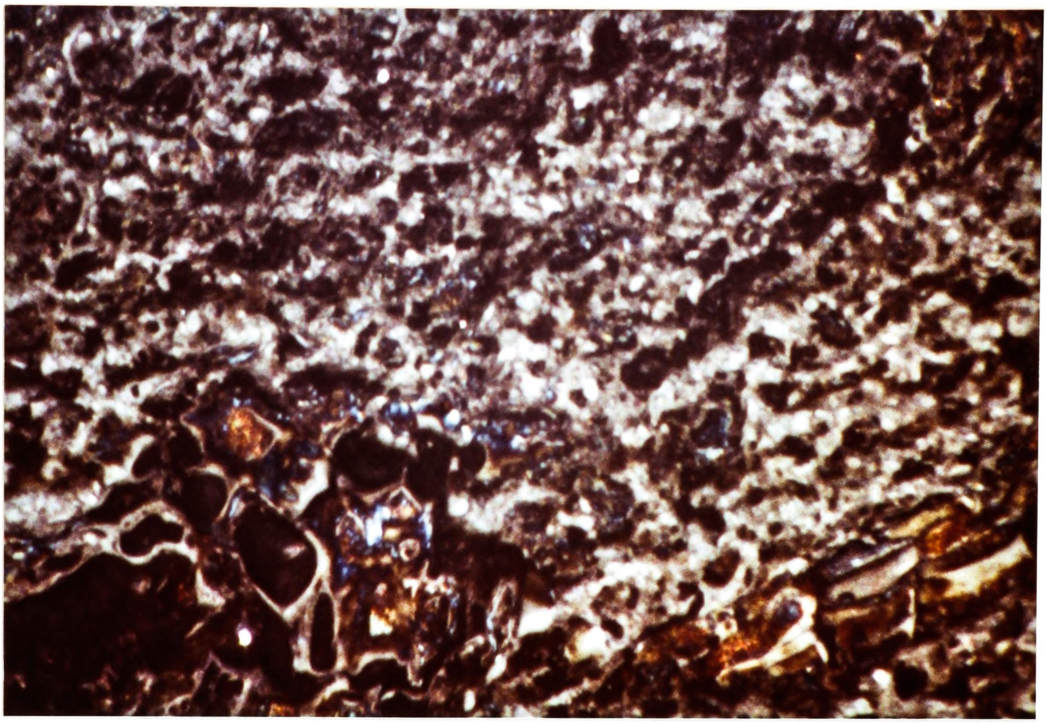
Lithotype - Medium Light (X200) Sample No 47



PM 10

Bands of Eugelinite Traversing Densinite

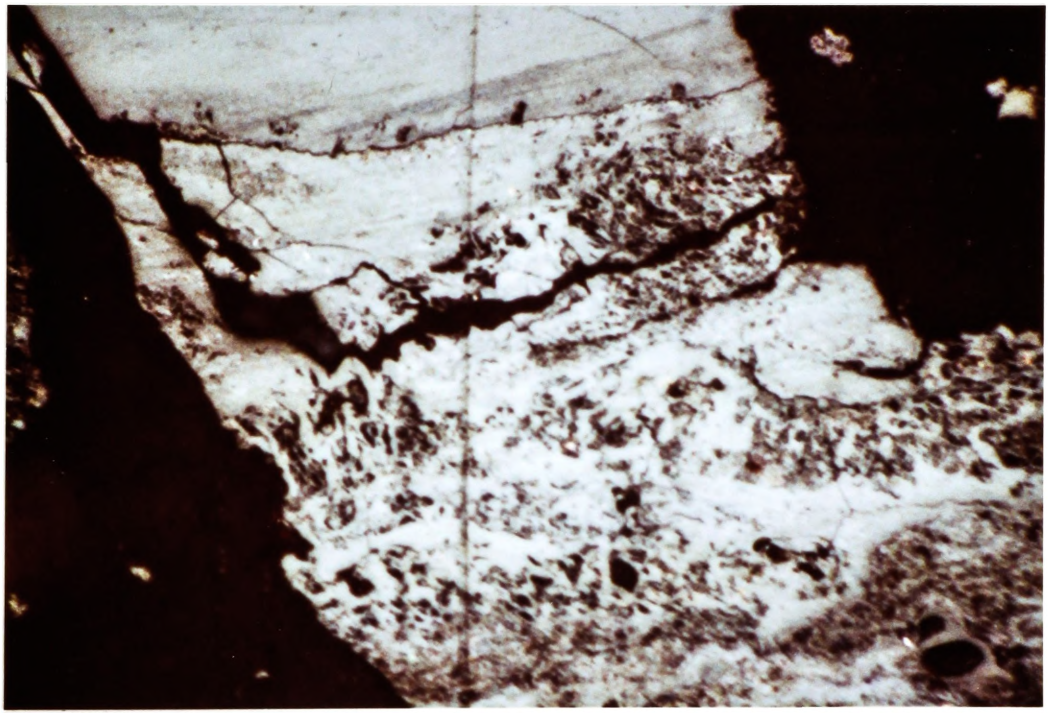
Lithotype - Dark (X500) Sample No 1



PM 11

Densinite with Texto-Ulminite

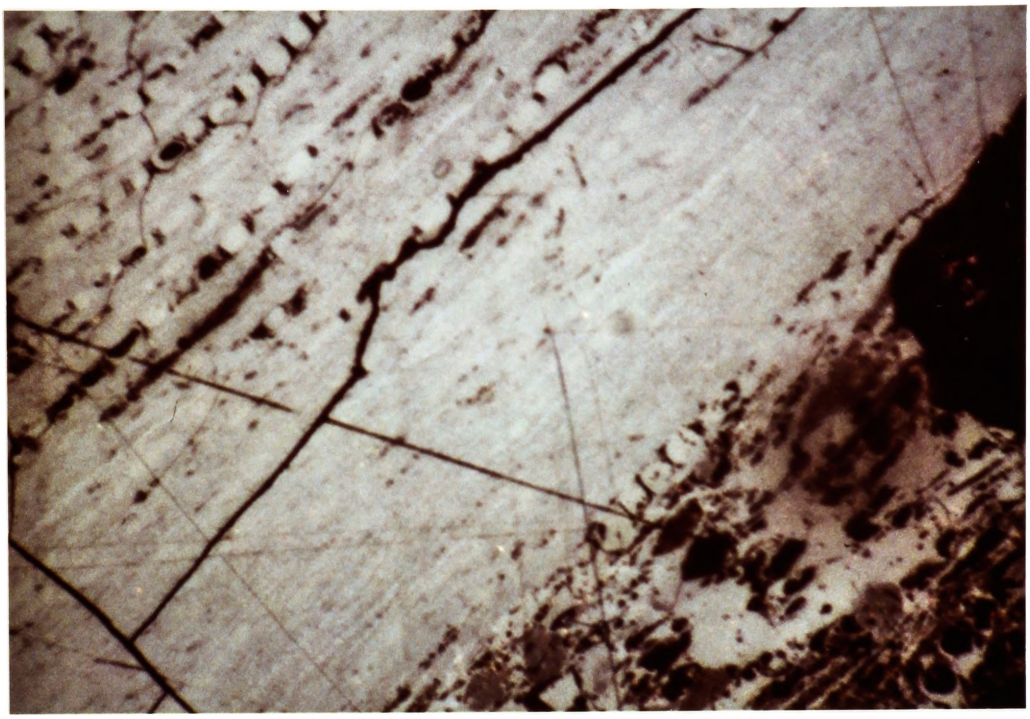
Lithotype - Dark Sample No 1
(X200)



PM 12

Texto-Ulminite Grading Through Eu-Ulminite to Telogelinite

Lithotype - Medium Dark Sample No 39
(X200)



PM 13

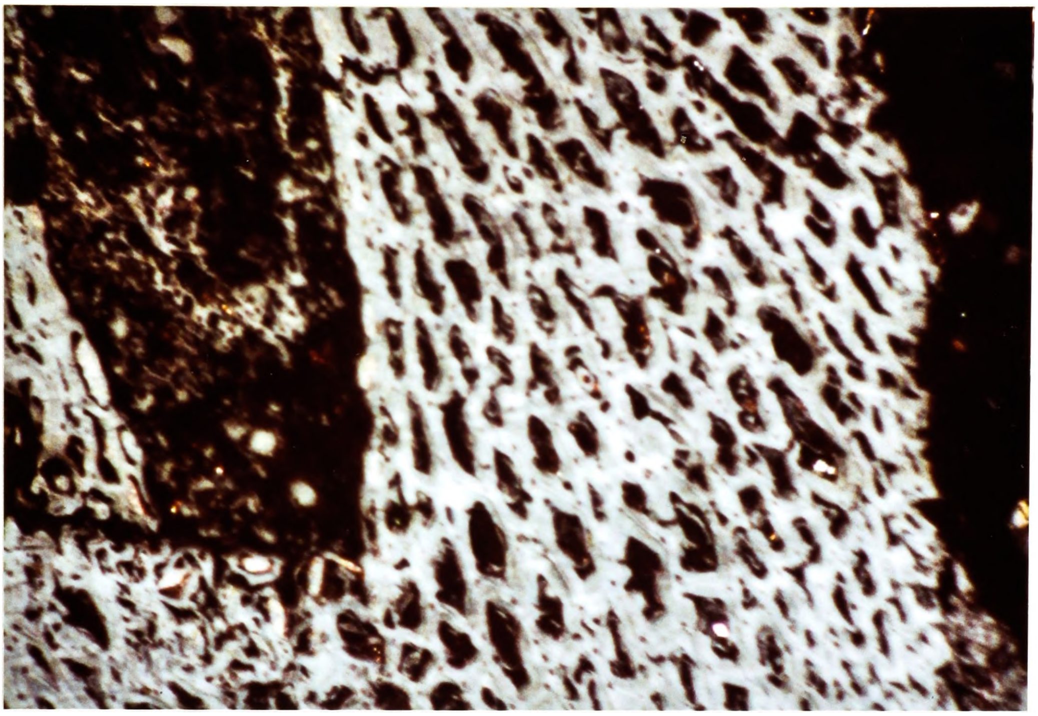
Telogelinite Grading into Eu-Ulminite

Lithotype - Medium Dark Sample No 38
(X200)

PM 14

Eu-Ulminite

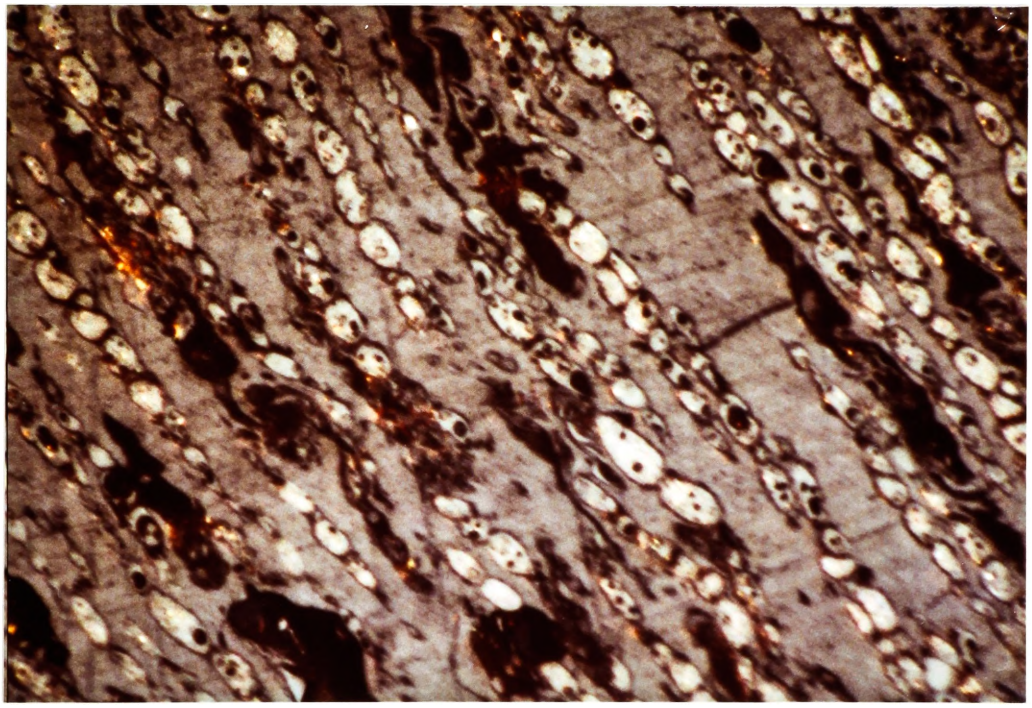
Lithotype - Medium Dark Sample No 38
(X200)



PM 15

Texto-Ulminite Displaying Characteristic Thickening of Cell Walls, Probably Conifer Wood

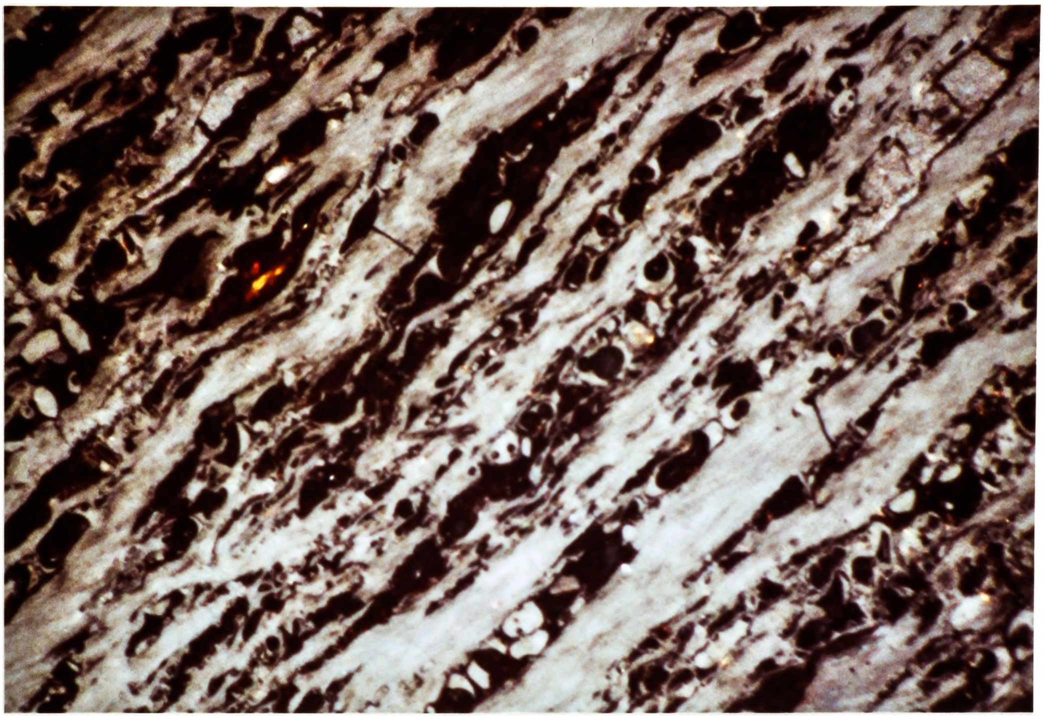
Lithotype - Medium Dark (X200) Sample No 6



PM 16

Texto-Ulminite (Approaching Eu-Ulminite) Containing Abundant Phlobaphinite

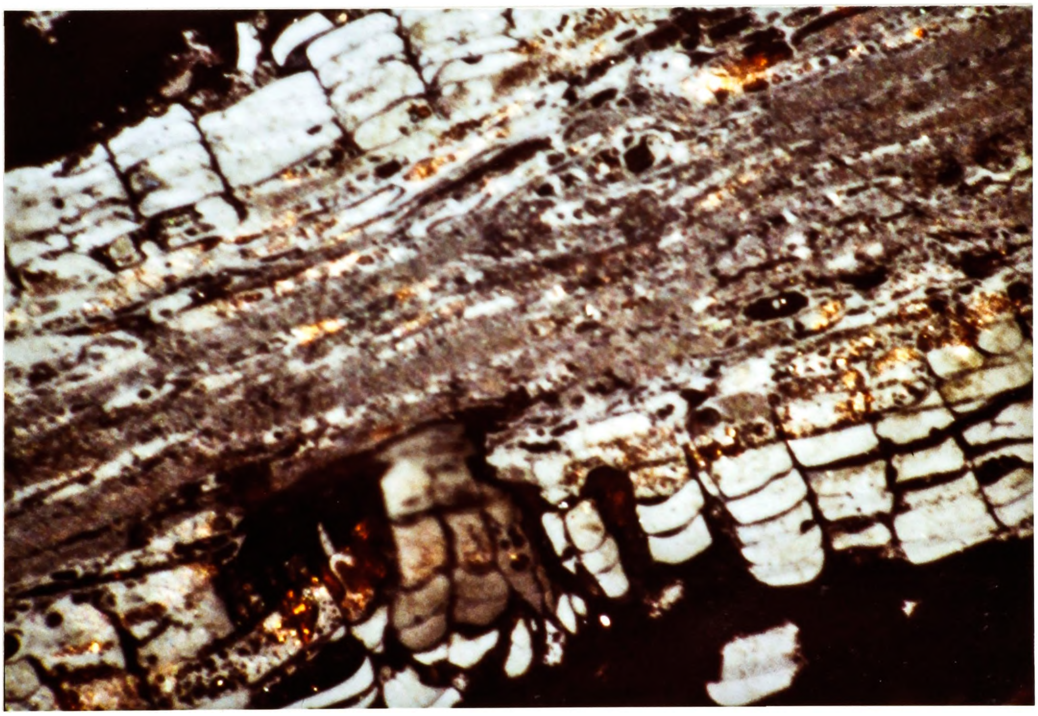
Lithotype - Medium Light (X200) Sample No 33



PM 17

Texto-Ulminite Tending Towards Eu-Ulminite

Lithotype - Medium Light Sample No 32
(X200)



PM 18

Eu-Ulminite and Phlobaphinite (Light Grey Infilling of Cell Lumens)

Lithotype - Dark Sample No 1
(X200)

PM 19

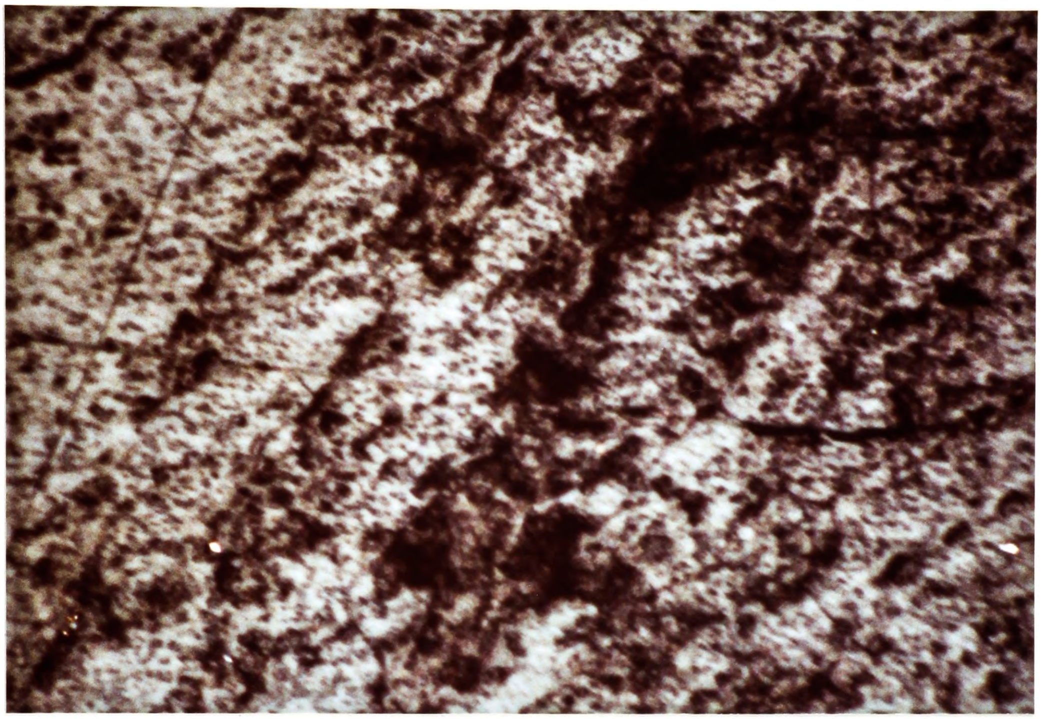
Texto-Ulminite in Advanced Stage of Gelification (Approaching Eu-Ulminite)

Lithotype - Medium Dark Sample No 39
(X200)

PM 20

Texto-Ulminite Showing Development Towards Eu-Ulminite

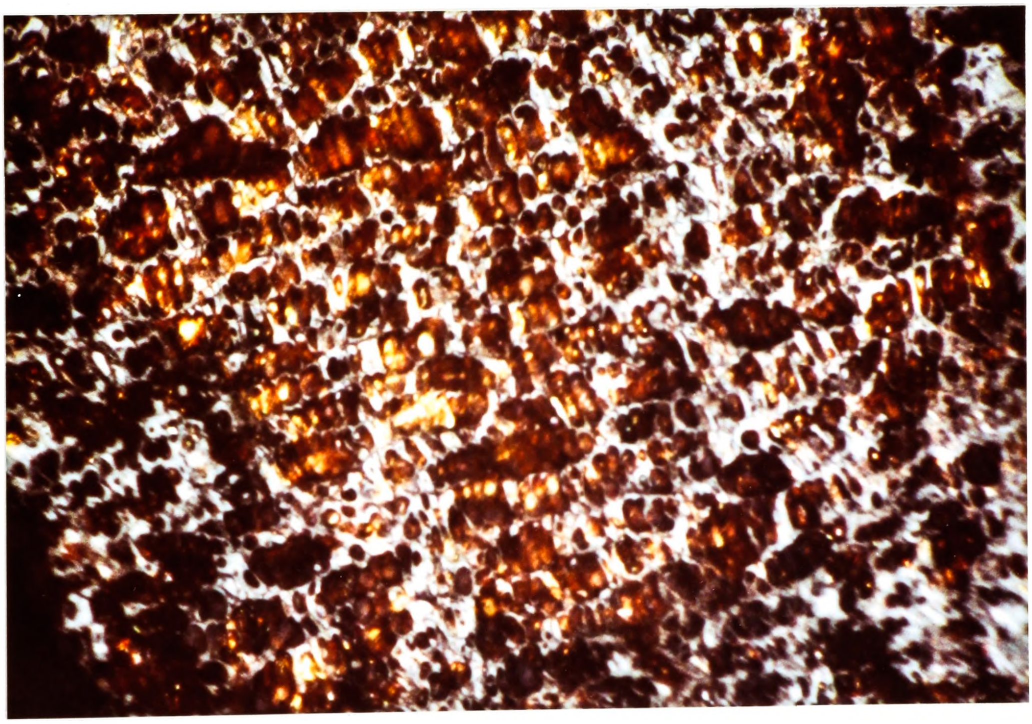
Lithotype - Medium Light Sample No 40
(X200)



PM 21

Highly Gelified, Fine Structured Texto-Ulminite

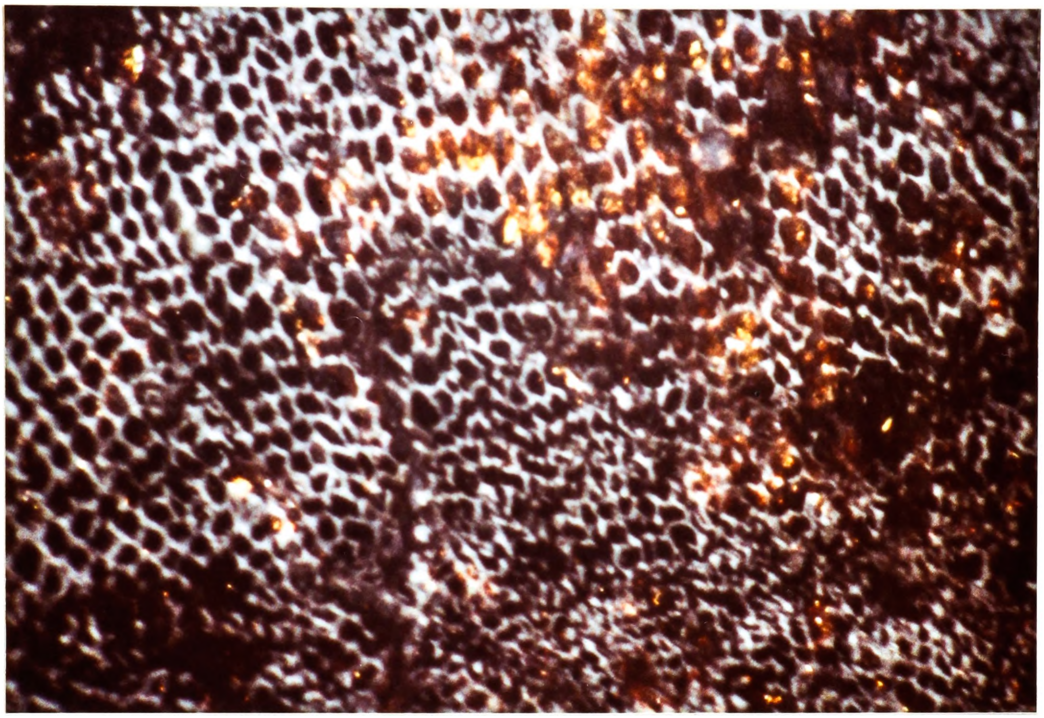
Lithotype - Light　　　　　　　　　　Sample No 49
(X200)



PM 22

Textinite (Red and Brown Colours Due to Internal Reflections in Open Cell Lumens)

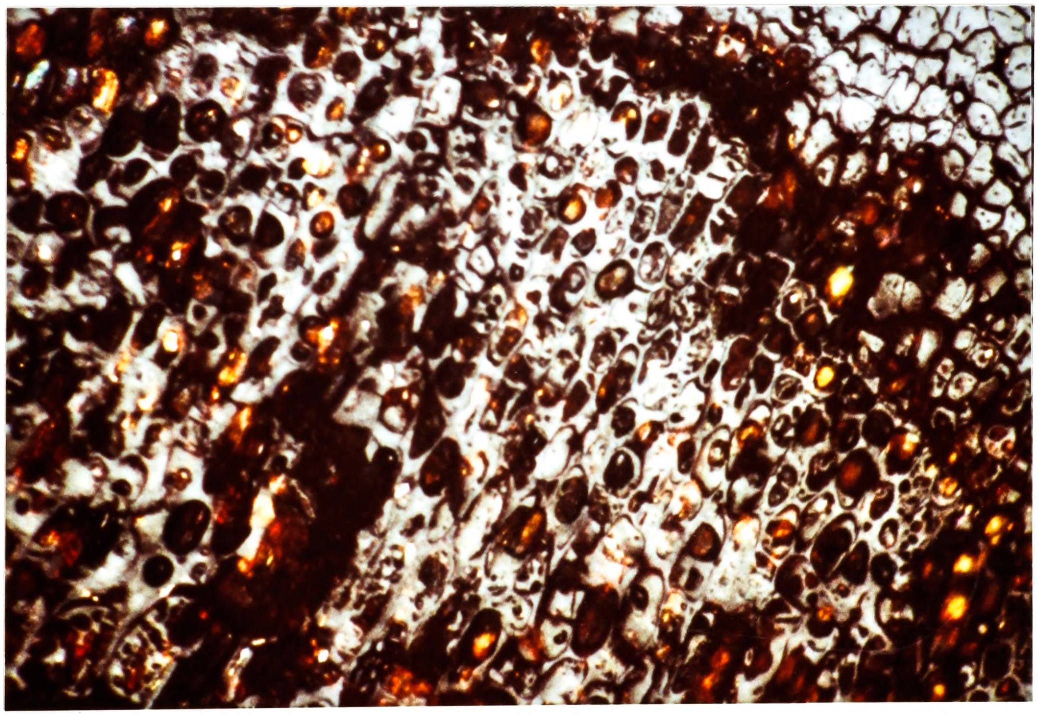
Lithotype - Medium Light　　　　　　　　　　Sample No 33
(X200)



PM 23

Textinite

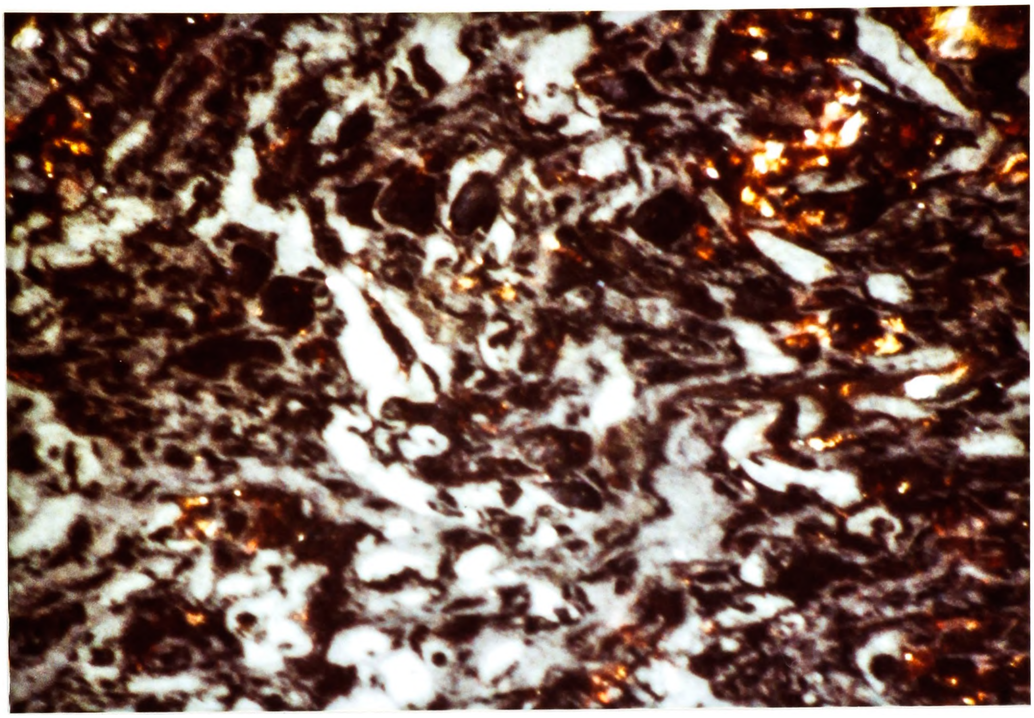
Lithotype - Light (X200) Sample No 34



PM 24

Texto-Ulminite Featuring Phlobaphinite (Infilling of Cell Lumens) and Probable Pseudo-Phlobaphinite (Partial Infilling)

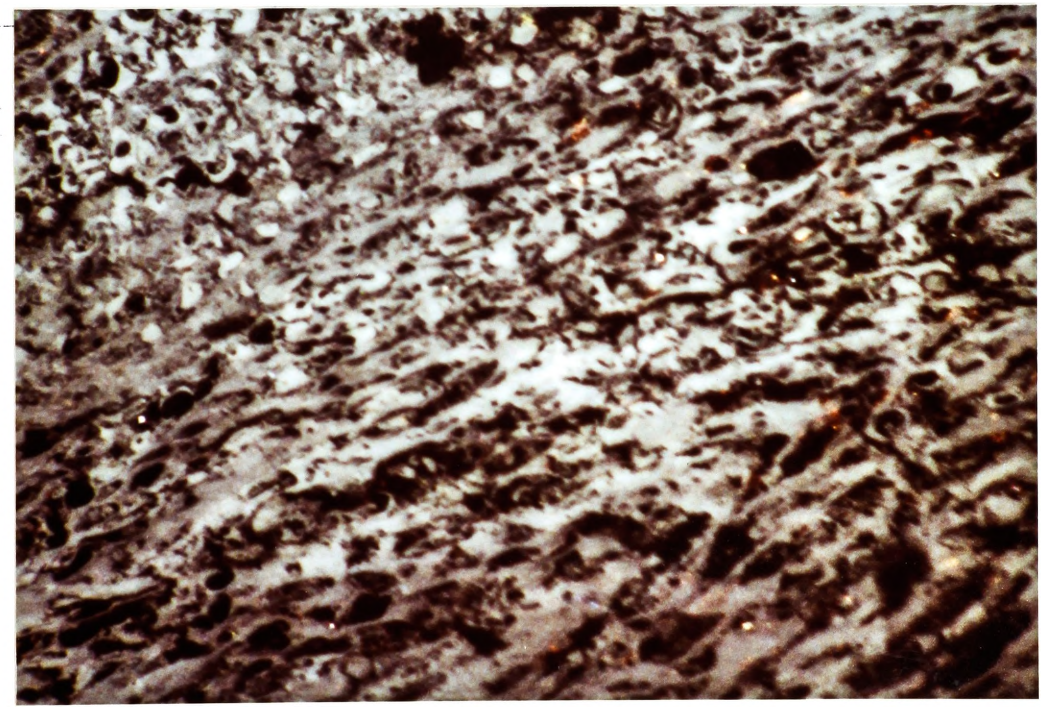
Lithotype - Medium Light (X200) Sample No 31



PM 25

Deformed Texto-Ulminite and Phlobaphinite

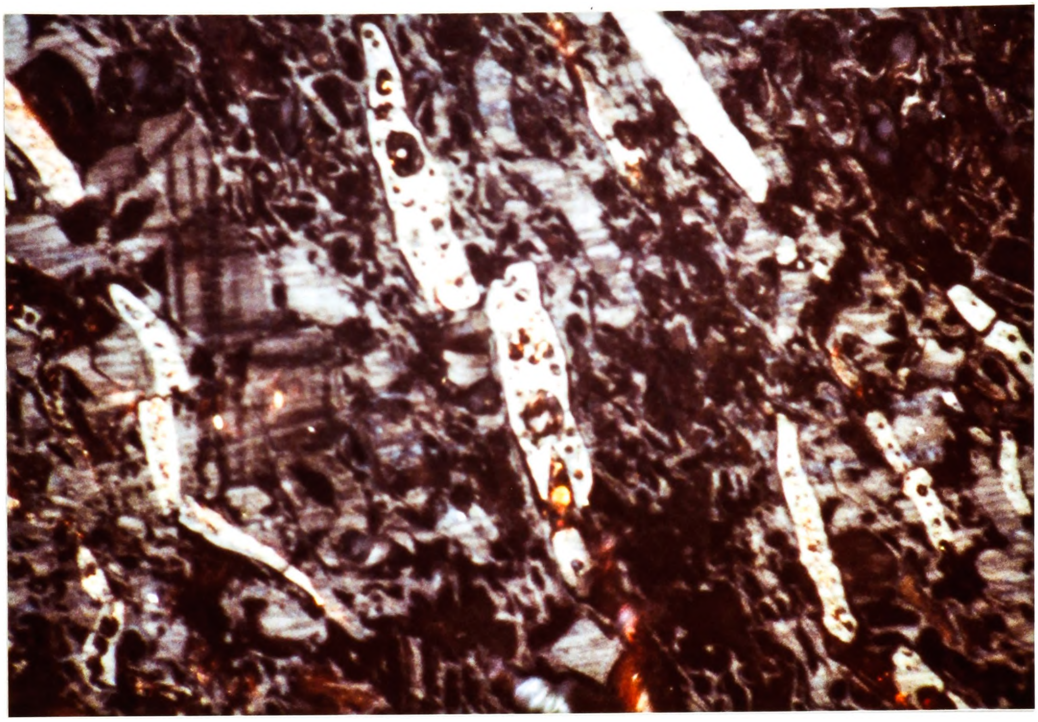
Lithotype - Medium Light (X200) Sample No 17



PM 26

Texto-Ulminite

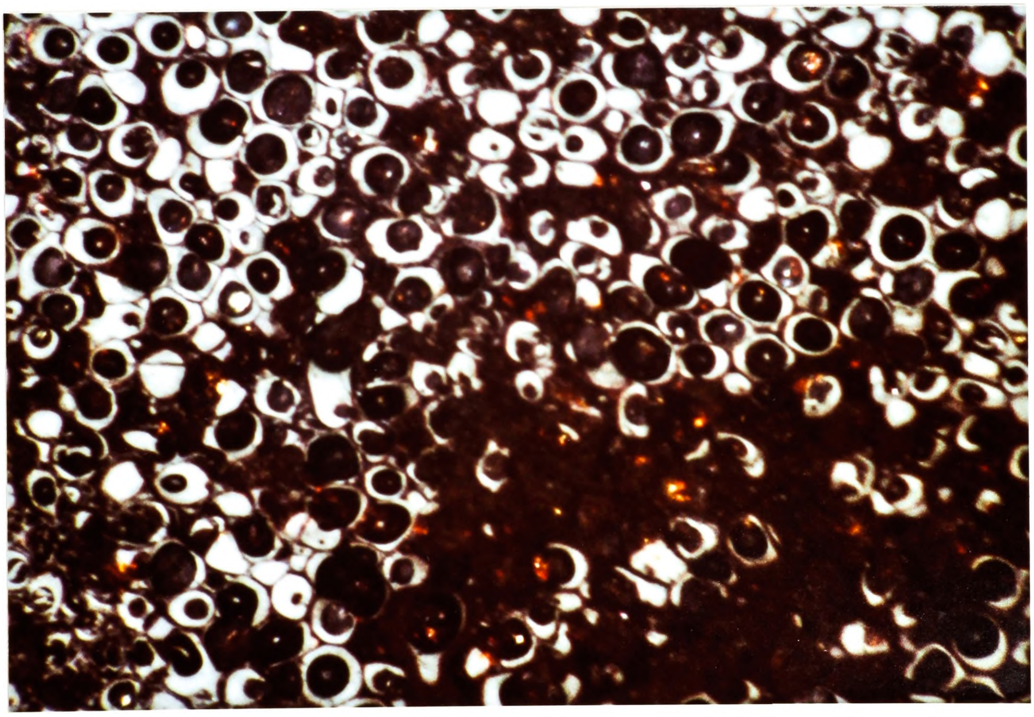
Lithotype - Medium Light (X200) Sample No 4



PM 27

Crushed Texto-Ulminite and Phlobaphinite

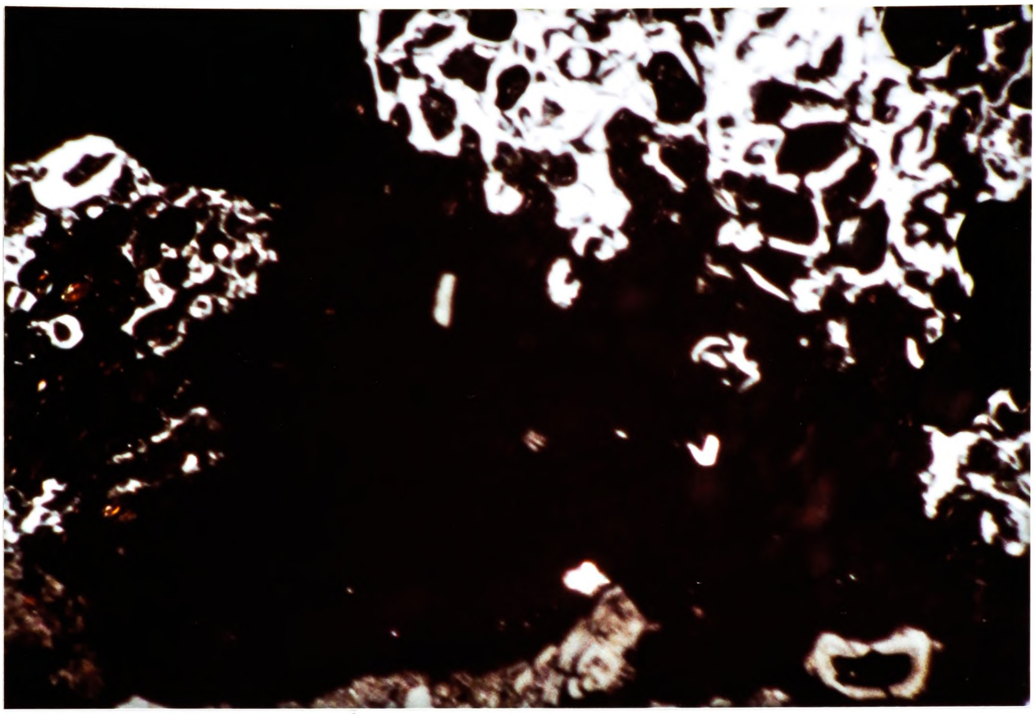
Lithotype - Light Sample No 48
(X200)



PM 28

Textinite Containing Probable Pseudo-Phlobaphinite (Light Coloured Material)

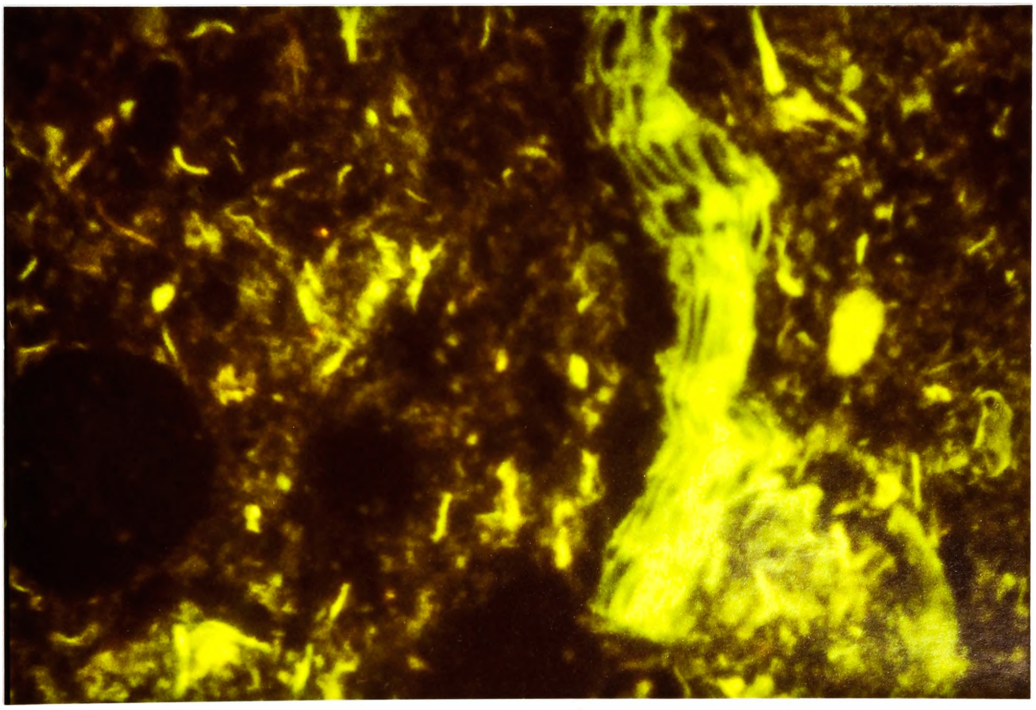
Lithotype - Medium Light Sample No 36
(X200)



PM 29

Fusinite and Semi-Fusinite

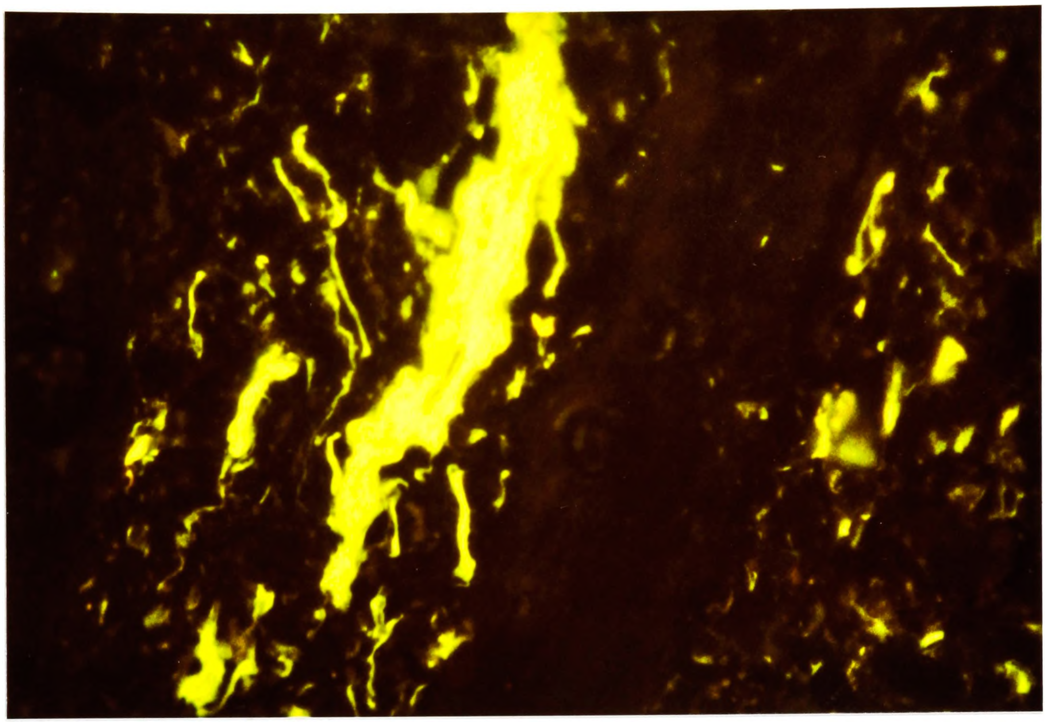
Lithotype - Dark Sample No 1
(X200)



PM 30

Liptodetrinite (Fluorescing Detritus), Sporinite (Identifiable Spore and Pollen Tests) and Suberinite (Visible Cellular Tissue)

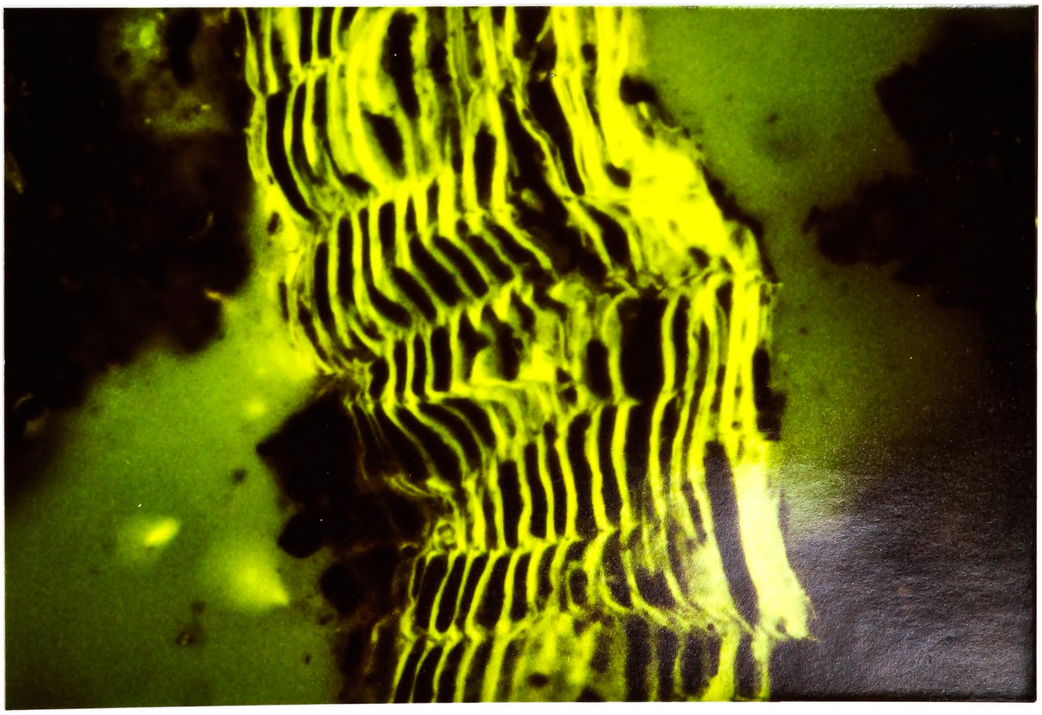
Lithotype - Pale Sample No 42
(X320 - Blue Light Excitation)



PM 31

Compressed Suberinite with Liptodetrinite

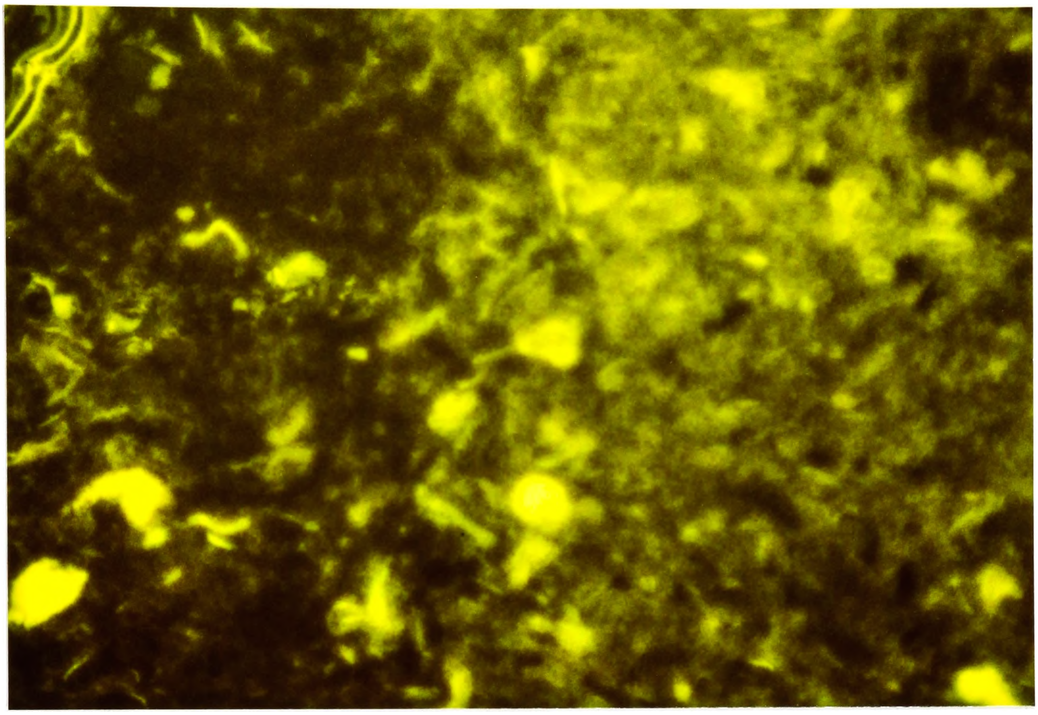
Lithotype - Medium Light Sample No 33
(X320 - Blue Light Excitation)



PM 32

Suberinite (Pale Greenish Areas are Embedding Resin

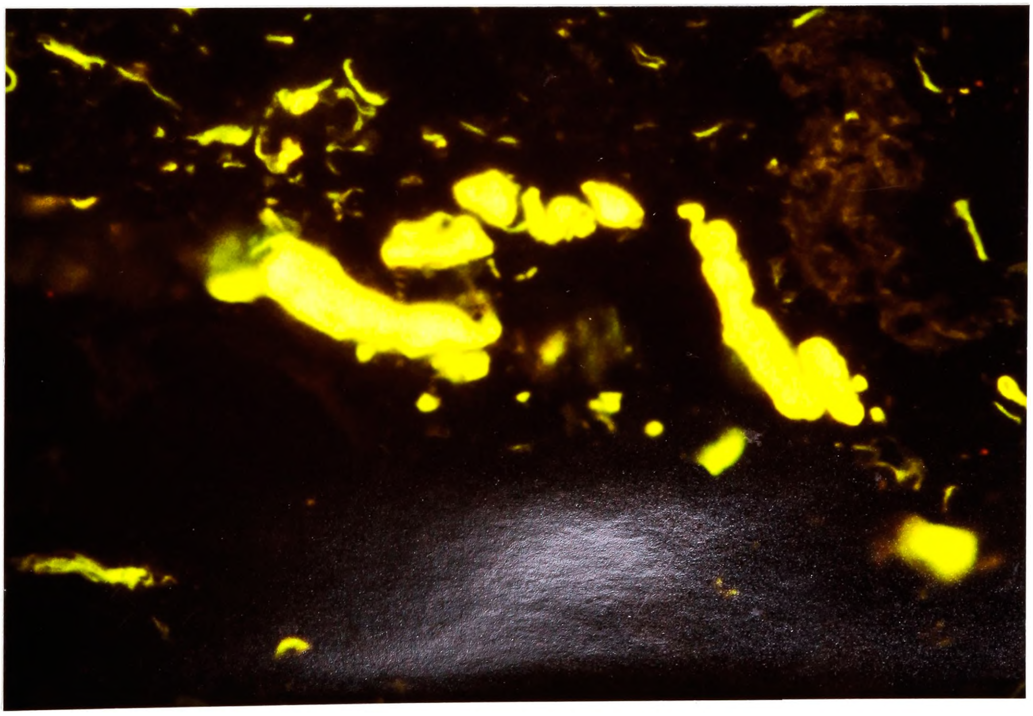
Lithotype - Medium Light Sample No 32
(X320 - Blue Light Excitation)



PM 33

Liptodetrinite and Resinite

Lithotype - Pale Sample No 43
(X320 - Blue Light Excitation)



PM 34

Resinite

Lithotype - Light Sample No 49
(X320 - Blue Light Excitation)